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<b>(54) Title:</b> SOURCE ADAPTIVE DIGITAL SUBSCRIBER LINE AND METHOD  <b>(57) Abstract</b>  A communication system includes plurality of subscribers having a telephone set and different types of home modems coupled using twisted pairs to a local server that includes plurality of downstream repeaters, a central office coupled to a local server using twisted pair subscriber lines. The central office includes a telephone switch that provides telephone service to the subscribers and a concentrator that connects a plurality of upstream repeaters with a number of office modems that provide data service to the subscriber. A communication system uses CAP or DMT line signals with time division. The line signal transmits with different time framing. Every subscriber line can work in one of three operation modes: Asymmetrical mode, Half-Asymmetrical mode, Symmetrical mode. An office modem changes the operation mode of subscribers line and downstream/upstream bit rate depending on the type of an information source and the type of the subscriber home modem that is connected to the office modem in the current transmit cycle.		

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## SOURCE ADAPTIVE DIGITAL SUBSCRIBER LINE AND METHOD.

### TECHNICAL FIELD OF INVENTION

The invention relates in general to data communication, and more particularly to Digital Subscriber Line on telephone cable.

### BACKGROUND ART OF THE INVENTION

Digital Subscriber Line (DSL), a new modern technology, converts existing twisted pair telephone lines into access paths for multimedia and high speed data communications. The most successful Asymmetric Digital Subscriber Line (ADSL) transmits more than 6 Mbps to the subscriber, and as much as 640 kbps in both directions. Such rates expand existing access capacity by a factor of 50 or more without new cabling. ADSL can practically transform the existing public information network from one limited to voice, text and low resolution graphics to a powerful, ubiquitous system capable of bringing multimedia, including full motion video, to every home.

An ADSL circuit connects an ADSL modem on each end of a twisted-pair telephone line, creating three information channels - a high-speed downstream channel, a medium speed duplex channel and a POTS (Plain Old Telephone Service) channel. The POTS channel is split off from the digital modem by filters, thus guaranteeing uninterrupted POTS, even if ADSL fails. The high-speed downstream channel ranges from 1.5 to 6.1 Mbps, while duplex rate range from 16 to 640 kbps. Downstream data rates depend on a number of factors, including the length of the copper line, its wire gauge, presence of bridged taps and cross-coupled interference. Line attenuation increases with line length and frequency, and decreases as wire diameter increases. Ignoring bridges taps, ADSL will perform as follows:

DATA RATE	WIRE SIZE	DISTANCE
1.5 MBPS	0.5 mm	5.5 km
1.5 MBPS	0.4 mm	4.6 km
6.1 Mbps	0.5 mm	3.7 km
6.1 Mbps	0.4 mm	2.7 km

One problem is that a real telephone cable has many bridges taps that significantly decrease line length. Another problem is that the flat telephone cable is used for wiring building. Practically these problems render impossible to provide 6.1 Mbps service for more than 30% of the subscribers. The ADSL home modem is a very complex and expensive apparatus. ADSL Central Office Equipment is very expensive too, because every subscriber line must have his own ADSL Office Modem. The Cost of Central Office ADSL Equipment may be as high as 300 U\$ per subscriber.

ADSL modem was developed to maximize performances for all available lines. The result is a high performance modem but not always the most cost-effective solution.

ADSL is not cost-effective due to the following reasons:

- DLC's or remote exchanges connect customers located at distances up to 9000 ft from the exchange. Obviously, full high performance ADSL is not needed for such a short lines. A more economical solution is required.
- Current ADSL requires one dedicated central office (C.O) unit for every customer. This is a very inefficient concept since most of the time only part of the lines is in use so there is always quite many central office units that are not in use. This inefficiency increases cost per line and space needed for ADSL equipment installation. The same service can be provided with smaller number of units at the C.O side together with concentration.
- ADSL was designed to maximize the data rates on the connection between the customer and the C.O however, this is usually not the limiting factor. Current Internet communication is limited today by the Internet's back bone

so increased ADSL data rates will not be truly translated to higher end to end communication. This is why lately a G.lite standard defined lower target for the data rates.

- ADSL today is a very complex and expensive apparatus at both C.O and customer side.
- ADSL was defined to maximize data rates without taking into account the characteristics of the various applications. Some applications require high downstream bit rate with very small upstream bit rate e.g. high quality video. Other applications require mid range symmetric data rates like video conferencing. Current ADSL supports maximal uplink and downlink data rates both at the same time. The result is a more complex solution that supports more than what is actually needed.

From another point of view ADSL is a very redound system, because ADSL was developed for maximal use of bandwidth for telephone cable without considering Information Sources Characteristics.

Another problem of existing ADSL system is that only one computer of subscribers may be connected to an Internet service at the same time .

About 15 million subscribers in the USA have at least 2 computers at home and since it is impossible to connect every home computer to Internet by the same twisted pair, the existing ADSL service limitation is a clear drawback.

## SUMMARY OF THE INVENTION

In accordance with the present invention, the disadvantages and problems associated with ADSL system have been substantially reduced or eliminated. In particular, the Source Adaptive Digital Subscriber Line (SADSL) provides data service to a subscriber in three operation modes: asymmetric mode, half-asymmetric mode and symmetric mode, according to the information source characteristics.

The SADSL uses QAM or DMT modulation for transmitting downstream and upstream data. The symbol rate of the upstream signal is several times less than the symbol rate of the downstream signal. SADSL transmits downstream and upstream data on the same twisted pair of telephone cable using time division method (TDM). The transmission frame of SADSL includes a downstream time interval for downstream symbols and an upstream time interval for upstream symbols. The transmission frame of SADSL has a constant duration in any operation mode but downstream and upstream time intervals have a different duration in different operation modes. Symbols of the synchronization word and symbols of the frame control word are added to downstream data symbols. Symbols of the acknowledges word are added to upstream data symbols.

In accordance with the present invention, information sources that may be connected to the subscriber end of SADSL are divided into three groups:

1. Asymmetrical information sources. These sources requires high bit rate downstream and produce only output control signals with a very low bit rate.

	Downstream	Upstream
This Group includes:		
Digital TV	6.1Mbps	16 Kbps
Digital HI FI AUDIO	1.5 MBPS	16 Kbps
Compressed Video	1.5 MBPS	16 Kbps

This Group relates to following situation: the subscriber only receives data from network server.

2. Half-asymmetrical information sources. These sources receive high bit rate downstream data and produce upstream data with low bit rate.

	<b>Downstream</b>	<b>Upstream</b>
This Group includes Internet	~ 1.0 Mbps	~ 100Kbps

This Group relates to following situation: the subscriber receives data from a network server and transmits data to a network server.

3. Symmetrical information sources. These sources require the same middle bit rate upstream data and downstream data.

	<b>Downstream</b>	<b>Upstream</b>
This Group includes Video Conference and Video Phone	384 kbps	384 kbps

This Group relates to following situation: information can be exchanged between subscribers.

Since the amount of information produced by one subscriber is significantly less than the amount of information produced by a network server, every current and future data services will be related to one of the three groups mentioned above.

The Source Adaptive Digital Subscriber Line may work in one of three operation modes, corresponding to three groups of information sources. Selection of the operation mode is implemented during initialization phase of the communication session. A communication session means here the cycle

of information exchange with the current information source. There are many communication sessions with different sources during one connection to a subscriber.

The SDSL Central Office may support communication many different home modems located at the same house and in different houses as well. Various upstream and downstream data bit rates can be supported. The initialization process of connection to a subscriber implements selection of data bit rates.

In accordance with the present invention, the SDSL communication system includes a plurality of different home modems, located at a plurality of subscriber premises and coupled to number of different information sources, located at each subscriber premises.

Every home modem has an information source analyzer and frame control circuit that changes the transmission frame in accordance with the type of information source connected to the home modem during the current communication session.

The SDSL communication system includes a central office coupled to plurality twisted pair subscriber lines. The central office includes a number of central office modems that may operate with any home modem. It should be noted that each C.O modem could support more than one customer. This functionality is achieved by connecting the C.O modems to the subscriber lines through analog concentrator. Every office modem has a home modem type analyzer, a frame control circuit and a bit rate adapter. The office modem changes its transmission frame structure and up/downstream bit rate in accordance with the home modem type and the information source type of the subscriber currently connected to this office modem. The number of office modems is smaller than the number of subscriber lines.

In accordance with one embodiment of the present invention, a communication system comprises a local server. The local server is located at the subscriber end of plurality twisted pair subscriber lines, routed to a building or telephone box. The local server includes plurality downstream



repeaters, coupled to twisted pair subscriber lines. The downstream repeater amplifies the downstream signal and splits the twisted pair subscriber lines into a twisted pair data line and a twisted or flat pair phone line.

In accordance with another embodiment of the present invention, a communication system is comprised of a central office including plurality upstream repeaters coupled to twisted pair subscriber lines. The upstream repeater amplifies upstream signal and splits each twisted pair subscriber line into a downstream data line, upstream data line and a twisted or flat pair phone line.

In accordance with another embodiment of present invention, a communication system is comprised of multiple line repeaters, coupled to twisted pair subscriber lines. The line repeater amplifies the upstream signal and downstream signal level. The line repeater includes a frame control circuit that is coupled to a synchronization block. The synchronization block receives the downstream synchronization signal.

In accordance with another embodiment of the present invention, a communication system is comprised of several home modems on subscriber end, connected to the same twisted pair. Every modem is connected to its own information source. Every home modem has an information source analyzer and frame control circuit that changes the transmission frame in accordance with the type of information source connected to the home modem, during the current communication session.

Every home modem includes super-frame control circuits that produce different transmission frames for different active home modems.

Control of the super-frame circuits of several home modems is achieved by a Central Office Modem connected to a subscriber line in the current communication session. This means that the Office modem transmits data to one active home modem during, for example, the first transmission frame and to another active home modem, during the second transmission frame. The super-frame includes, for example, 4 transmission frames. Every transmission

frame may work in one of three operating modes, according to the connected information source. During the 3<sup>rd</sup> and 4<sup>th</sup> frame transmission of the super-frame, data transmission between active home modems can take place. This means that the SADSL system in this embodiment provides not only DSL service but includes home digital network functionality i.e. the ability to communicate between units located at the customer premises side.

In accordance with another embodiment of the present invention, a communication system is comprised at subscriber end one or several home modems and a Digital Telephone Set connected to the same twisted pair. The Digital Telephone Set includes PCM or ADM codec and a frame control circuit that is coupled to a synchronization block. This block receives a downstream synchronization signal. The voice signal is coded by PCM or ADM codec and is transmitted during a part of the time interval reserved for control data and synchronization signals.

Important technical advantages of the present invention include ability of SADSL to adapt characteristics of home and office modems to characteristics of the current information source. This advantage makes it possible to develop simple home modems that satisfy all the needs of a subscriber.

Another important technical advantage of the present invention includes ability of SADSL to work with different types of home modems and supports many different downstream and upstream data bit rates.

The SADSL communication system may service simultaneously a number of cheap home modems with low data bit rate and a number of expensive home modems with a high data bit rate.

Another important technical advantage of the present invention includes the ability to amplify and split SADSL line signals using a simple repeater. In the SADSL communication system there is no limitation of cable length and bridge taps. Practically every subscriber of the existing telephone network may be connected to the SADSL communication system.

Another important technical advantage of the present invention includes the ability to give service to a plurality of subscriber home modems with a reduced number of office modems. This advantage makes the SADSLS system a more economical solution than the existing ADSL system.

Another important technical advantage of the present invention includes the ability to provide DSL service and Home Digital Networking service by the same home modem simultaneously.

Another important technical advantage of the present invention includes the possibility to provide Digital Telephone Service on the same twisted pair that is used for DSL and POTS service. It should be noted that the present invention is line code independent. The invention relates to modems utilizing base band modulation such as PAM, single carrier modulation such as QAM or CAP or multi carrier modulation such as discrete multi tone (DMT).

One important embodiment of the invention is based on some variant of the current ADSL standard. This variant is the special standard defined for the Japanese market and is known as G.dmt annex C. Some slight variations to this standard can set the basis for the implementation of the present invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, and for further features and advantages, reference is now made to the following description taken in conjunction with the accompanying drawings, in which :

FIG.1 illustrates a communication system that provides telephone and data service .

FIG.2 illustrates a transmission frame structure in asymmetrical mode for QAM SADSL.

FIG.3 illustrates a transmission frame structure in half-asymmetrical mode for QAM SADSL .

FIG.4 illustrates a transmission frame structure in symmetrical mode for QAM SADSL.

FIG.5 illustrates a data transport cell structure.

FIG.6 illustrates a transmission frame structure in asymmetrical transmit mode for DMT SADSL.

FIG.7 illustrates a transmission frame structure in half-asymmetrical mode for DMT SADSL.

FIG.8 illustrates a transmission frame structure in symmetrical mode for DMT SADSL .

FIG.9 illustrates in more details the home modem..

FIG.10 illustrates in more details the downstream repeater.

FIG.11 illustrates in more details the line repeater.

FIG.12 illustrates in more details the upstream repeater.

FIG.13 illustrates in more details the central office modem.

FIG.14 is a flow chart of a communication system operation.

Fig .15 illustrates how the communication system provides DSL and Home network service simultaneously.

Fig.16 illustrates in more details the home modem.

Fig.17 illustrates in more details the office modem.

Fig. 18 illustrates transmission superframe structure in the configuration depicted in Fig. 15.

Fig. 19 is a time diagram of the communication system providing DSL and Home Network Service simultaneously.

Fig. 20 illustrates the communication system providing DSL, Home Network and digital telephone service simultaneously.

Fig. 21 illustrates transmission of the frame structure of the communication system with digital telephone service in QAM application.

Fig. 22 illustrates in more details the Digital Telephone Set in QAM application.

## DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates the communication system 20 that provides both telephone and data service to subscriber 22. Subscriber 22 is coupled to local server 24 using local data line 26 for data communication and local phone line 28 for telephone communication. A local data line 26 and a local phone line 28 may use a twisted pair or a flat pair. A Central office 30 is coupled to local server 24 using twisted pair subscriber lines 32. Subscriber lines 32 support simultaneous telephone and data service.

Subscriber 22 includes telephone 34 and home modem 36. Telephone 34 is coupled to local phone line 28. Home modem 36 is coupled to local data line 26. Telephone 34 is a traditional telephone transceiver, or any other device suitable for allowing voice communication over telephone line 28.

Home modem 36 transmits and receives data in communication system 20 using QAM or DMT modulation signals. Home modem 36 is coupled with three groups of information sources: symmetrical group 38, half-asymmetrical group 40, asymmetrical group 42.

Symmetrical source 38 has the same middle range bit rate for both upstream and downstream direction. One example of this source is Video Phone. Half-asymmetrical source 40 receives high bit rate downstream and produces upstream with low bit rate. The example of this source can be personal computer connected to the Internet. Asymmetrical source 42 receives high bit rate downstream data and produces only output control signals with very low bit rate. Such source can be digital TV.

Communication system 20 includes a number of other twisted pair subscriber lines 32 coupled to other subscribers 22 through local server 24. In a typical embodiment, Central Office 30 provides phone and data services to one thousand subscribers 22. A local server 24 provides phone and data service to all subscribers into a building and includes a number of downstream repeaters 44 in accordance with the number of subscribers. Downstream Repeater 44

increases the level of the received downstream signal from Central Office, splits data and phone signals and transmits them to subscriber 22, using local twisted pair 26 for data and local phone line 28 for phone. Line repeater 45 that increases the level of downstream and upstream line signals, may be included at long subscriber line 29, 31.

Central office 30 includes a number of upstream repeaters 46 coupled to subscriber line 32, a number of office modems 58, concentrator 56, telephone switch 54 and network device 72.

Upstream Repeater 46 increases the level of upstream signal received from subscriber 22, splits data and phone signals into three lines: phone line 48, downstream data lines 50 and upstream data line 52.

Phone line 48 is coupled with telephone switch 54. A telephone switch 54 at central office 30 provides plain old telephone system (POTS) service to subscribers 22.

Downstream data line 50 and upstream data line 52 are coupled to concentrator 56 that connects a number of subscribers 22 to a number of office modems 58 using modem up line 60 and modem down line 62.

Concentrator 56 provides electrical connection among a number of subscribers 22 and a number of office modems 58. The number of office modems 58 is less than the number of subscribers 22.

Concentrator 56 performs off-hook detection to determine if subscriber 22 desires data service. The data off-hook detector in concentrator 56 can use one of several methods to determine whether subscriber 22 should be connected to an office modem 58. The off-hook detector in communication server 56 may monitor direct line current, voltage, electrical tones, data link frames, or any other protocol or data sequencing to determine whether subscriber 22 needs data access.

The following triggers for connecting subscriber line through the concentrator have special importance for DMT (ADSL based) implementation of the present invention:

- Detecting the appropriate activation/service request signal coming from the CPE side. Simple detector designed to detect the unique activation/G.hs signals used to initiate ADSL connection can do this detection. This trigger is used once when the ADSL link is first established.
- Energy detection on the upstream path. This trigger is used to reconnect existing link when both sides remained synchronized. Data transfer upon detection of this trigger is almost immediate and does not require re-train process.

Concentration session includes the following steps:

- Detection of some activation signal coming from the CPE side as was previously described.
- Allocating C.O modem to the active line through the concentrator.
- Upon detection of "no activity" on the line e.g. receiving idle cells during some predefined period - temporary disconnection of the line at the CO side.
- During this temporary disconnection period, synchronization is maintained between the CPE and C.O modems. This synchronization eliminates the need for a long re-train process. It is implemented by continues transmission of the pilot tone (DMT implementation) even during the temporary disconnection time.
- Upon activity detection, the active line will be reconnected through the concentrator to any available CO modem. The data connection will be rebuilt within a short period since the line parameters are already known and stored in system.

To allow synchronization during the temporary disconnection periods all C.O modems connected to the same concentrator are using the same clock source. If DMT line code is used, the pilot tone will be generated at the concentrator from one source and will be distributed to all the lines. The CO modems might



not generate the pilot tone by themselves even during normal operation - instead, the pilot carrier will be always added at the concentrator.

A Central Office **30** includes network device **72** that is coupled with Office Modem **58** by data line **74** and with Data Network **76** by network line **78**.

One embodiment of communication system **20** uses QAM or CAP modulation for transmitting upstream and downstream line signals. There are four levels of line signal depending on the necessary bit rate .

- a. Level 1 uses QAM 4 modulation for up and downstream.
- b. Level 2 uses QAM16 modulation for up and downstream.
- c. Level 3 uses QAM 64 modulation for up and downstream
- d. Level 4 uses QAM256 modulation for up and downstream.

The office modem **58** may operate at four levels of line signals. The current level of office modem **58** line signals depends on the type of home modem **36** that was connected by the subscriber in the current communication cycle. Home modem **36** may be different and may support one or several levels of line signals.

The simplest home modem GRADE 1 supports only Level 1.

Home modem GRADE 2 supports Level 1 and Level 2.

Home modem GRADE 3 supports Level 1, Level 2 and Level 3.

Home modem GRADE 4 supports all four levels of line signal.

Another embodiment of communication system **20** uses DMT modulation for transmission of upstream and downstream data transport cells **90** and QAM modulation for transmission of synchronization word **88**, frame control word **89** and acknowledge word **92**. Every tone of DMT can be modulated by QAM4, QAM16, QAM64, and QAM256 . In accordance with modulation type, there are four corresponding levels of DMT line signal.

Communication system **20** has three operation modes in accordance with the information source type that was used by the subscriber for the current transmission session: asymmetrical, half-asymmetrical and symmetrical mode of operation. There are three possible transmission frame structures, depending on the operation mode.

FIG.2 illustrates the transmission frame structure (of QAM home modem GRADE 1) for asymmetrical operation mode in one embodiment of the present invention. Transmission frame **80** has constant 4 ms duration and includes Downstream Interval **82**, Upstream Interval **84** and Gap Interval **86**. Downstream Interval **82** includes synchronization word (SW) **88**, control word (CW) **89** and following 16 data transport cells (DTC) **90** that contain downstream data. Upstream Interval **84** include only acknowledges (AK) **92**. Gap Interval (GI) **86** is the guard time for next transmission frame.

FIG.3 illustrates the transmission frame structure (of QAM home modem GRADE 1) for half asymmetrical operation mode in one embodiment of the present invention. In this mode Downstream Interval **82** includes SW **88**, CW **89** and 10 DTC **90**. Upstream Interval **84** includes AK **92** and 2 DTC **90**.

FIG.4 illustrates transmission frame structure (of QAM home modem GRADE 1) for symmetrical operation mode in one embodiment of the present invention. In this mode Downstream Interval **82** includes SW **88**, CW **89** and 4 DTC **90**. Upstream Interval **84** includes AK **92** and 4 DTC **90**.

FIG.5 illustrates data transport cell **90** structure. In Synchrony Transfer Mode (STM) DTC **90** supports two downstream data channels: AS0 and AS1 and two upstream data channels: LS0 and LS1. In this mode DTC **90** includes a control byte, 4 bytes of AS1/LS1 channel, 48 bytes of AS0/LS0 channel and 8 bytes of Rid-Solomon Code. In Asynchronies Transfer Mode (ATM), DTC **90** includes 53 bytes of ATM Cell and 8 bytes of Rid - Solomon Code. Communication system **20** uses the same synchronization word (SW) **88** and different codes for control word **89** and for acknowledge **92** corresponding to the operation mode and the current data bit rate. The Control word (CW) **89**

informs every device connected to the subscriber line (Home Modem, Office Modem, repeaters) in which operation mode the system must work in the current transmit frame and which type (GRADE) of Home Modem is connected to the subscriber end.

Frame synchronization word **88**, Control word **89** and acknowledge **92** are transmitted with the lowest level of modulation (QAM4) for any Grade of modems. Data Transport Cell **90** is transmitted with QAM4 for Level 1, QAM16 for Level 2, QAM64 for Level 3 and QAM256 for Level 4.

TABLE 1 shows the number of QAM upstream and downstream DTC **90** in one embodiment of the present invention for different operation modes. This data was calculated for 4ms duration of the transmission frame, symbol clock of downstream 1080 kHz and symbol clock of upstream 360 kHz.

**TABLE 1.** Number of DTC in QAM SADSL transmission frame.

MODE	ASYMMETRIC		HALF ASYMMETRIC		SYMMETRIC	
	UP	DOWN	UP	DOWN	UP	DOWN
<b>QAM 4</b>	<b>0</b>	<b>16</b>	<b>2</b>	<b>10</b>	<b>4</b>	<b>4</b>
<b>QAM 16</b>	<b>0</b>	<b>32</b>	<b>4</b>	<b>20</b>	<b>8</b>	<b>8</b>
<b>QAM 64</b>	<b>0</b>	<b>48</b>	<b>6</b>	<b>30</b>	<b>12</b>	<b>12</b>
<b>QAM 256</b>	<b>0</b>	<b>64</b>	<b>8</b>	<b>40</b>	<b>16</b>	<b>16</b>

TABLE 2 shows Transmit Capability of Communication System **20** (in ATM cells) in one embodiment of the present invention. This data was calculated for 4ms duration of the transmission frame, symbol clock of downstream 1080 kHz and symbol clock of upstream 360 kHz.

**TABLE 2.** QAM SADSL System Transmit Capacity in ATM cell/sec.

MODE	ASYMMETRIC		HALF ASYMMETRIC		SYMMETRIC	
	UP	DOWN	UP	DOWN	UP	DOWN
QAM 4	0	4000	500	2500	1000	1000
QAM 16	0	8000	1000	5000	2000	2000
QAM 64	0	12000	1500	7500	3000	3000
QAM 256	0	16000	2000	10000	4000	4000

TABLE 3 shows Transmit Capability of Communication System 20 (in STM mode) in one embodiment of the present invention. This data was calculated for 4ms duration of the transmission frame, symbol clock of downstream 1080 kHz and symbol clock of upstream 360 kHz.

**TABLE 3.** QAM SADSL System transmission Capacity (STM) in kbps.

MODE	ASYMMETRIC		HALF ASYMMETRIC		SYMMETRIC	
	UP	DOWN	UP	DOWN	UP	DOWN
		AS0+AS1	LS0+LS1	AS0+AS1	LS0+LS1	AS0+AS1
QAM 4	0	1536+128	192 + 16	960+80	384+32	384+32
QAM 16	0	3072+256	384+32	1920+160	768+64	768+64
QAM 64	0	4608+384	512+48	2880+240	1152+96	1152+96
QAM 256	0	6144+ 512	768+64	3840+320	1536+128	1536+128

FIG.6 illustrates transmission frame structure (of DMT home modem GRADE 1) for asymmetrical operation mode in another embodiment of the present invention. Transmission frame 80 has a constant of 4 ms duration and includes Downstream Interval 82, Upstream Interval 84 and Gap Interval 86. Downstream Interval 82 includes synchronization word (SW) 88, control word (CW) 89 and following 24 data transport cells (DTC) 90 that contain

downstream data. Upstream Interval **84** include only acknowledges (AK) **92**. Gap Interval (GI) **86** is used for defense of next transmission frame. Every DTC **90** is coded by DMT modulation that uses 244 tones with QAM4. Every downstream DTC **90** is converted to one 125  $\mu$ s DMT symbol, every upstream DTC is converted to one 375  $\mu$ s DMT symbol.

FIG.7 illustrates the transmission frame structure (of DMT home modem GRADE 1) for half asymmetrical operation mode in another embodiment of the present invention. In this mode Downstream Interval **82** includes SW **88**, CW **89** and 15 DTC **90**. Upstream Interval **84** includes AK **92** and 3 DTC **90**.

FIG.8 illustrates the transmission frame structure (of DMT home modem GRADE 1) for symmetrical operation mode in another embodiment of the present invention. In this mode Downstream Interval **82** includes SW **88**, CW **89** and 6 DTC **90**. Upstream Interval **84** includes AK **92** and 6 DTC **90**.

A Communication system **20** uses the same Frame synchronization word (SW) **88** and different codes for Control Word **89** and acknowledge **92** corresponds to the operation mode and current data bit rate. The Control word (CW) **89** informs every device that is connected to the subscriber line (Home Modem, Office Modem, repeaters) in which operation mode it must work in the current transmission frame and which type (GRADE) of Home Modem is connected to the subscriber end.

Frame synchronization words **88**, Control word **89** and acknowledges word **92** are transmitted with QAM4 for any Grade's of modems. Data Transport Cell **90** is transmitted with DMT that uses 244 tones with QAM4 for Level.1, QAM16 for Level.2, QAM64 for Level.3 and QAM256 for Level.4.

TABLE 4 shows the number of DMT upstream and downstream DTC **90** in another embodiment of the present invention for different operation modes. This data was calculated for 4ms duration of the transmission frame.

TABLE 4. Number of DTC in DMT SADSL transmission

MODE	ASYMMETRIC		HALF ASYMMETRIC		SYMMETRIC	
MODULATION	UP	DOWN	UP	DOWN	UP	DOWN
DMT 4	0	24	3	15	6	6
DMT 16	0	48	6	30	12	12
DMT 64	0	72	9	45	18	18
DMT 256	0	96	12	60	24	24

TABLE 5 shows Transmit Capability of Communication System 20 (in ATM cells) in DMT embodiment of the present invention. This data was calculated for 4ms duration of the transmission frame.

TABLE 5. DMT SADSL System Transmit Capacity in ATM cell/sec.

MODE	ASYMMETRIC		HALF ASYMMETRIC		SYMMETRIC	
MODULATION	UP	DOWN	UP	DOWN	UP	DOWN
DMT 4	0	6000	750	3750	1500	1500
DMT 16	0	12000	1500	7500	3000	3000
DMT 64	0	18000	2250	11250	4500	4500
DMT 256	0	24000	3000	15000	6000	6000

TABLE 6 shows Transmit Capability of Communication System 20 (in STM mode) in DMT embodiment of the present invention. This data was calculated for 4ms duration of the transmission frame.

TABLE 6. DMT SDSL System Transmit Capacity (STM) in Kbps.

MODE	ASYMMETRIC		HALF ASYMMETRIC		SYMMETRIC	
MODULATION	UP	DOWN	UP	DOWN	UP	DOWN
		AS0+AS1	LS0+LS1	AS0+AS1	LS0+LS1	AS0+AS1
DMT 4	0	2304+192	288 + 24	1440+120	576+48	576+48
DMT 16	0	4608+384	576+48	2880+240	1152+96	1152+96
DMT 64	0	6912+576	864+72	4320+360	1728+144	1728+144
DMT 256	0	9216+ 768	1152+96	5760+480	2304+192	2304+192

FIG.9 illustrates in more details home modem 36 in one embodiment of the present invention .

The home modem 36 includes line transformer 100 connected to twisted pair 26, upstream amplifier 102 that is coupled to transformer 100 and to QAM modulator 104, downstream amplifier 106 that is coupled to transformer 100 and to QAM demodulator 108, frame synchronizer 110 coupled to QAM demodulator 108 and to frame control circuit 112 , digital interface 122, coupled to QAM modulator 104 and to QAM demodulator 108 and information source analyzer 120 coupled to acknowledge generator 118. Information source analyzer 120 and digital interface 122 are coupled by digital line 128 to the symmetrical information source 38, by digital line 130, to half asymmetrical information source 40, by digital line 132, to asymmetrical information source 42. Acknowledge generator 118 is coupled to QAM modulator 104.

The downstream signal received from twisted pair 26 is converted by QAM demodulator 108. The binary sequence of decoded downstream data is transmitted to frame synchronizer 110 and to digital interface 122. The digital interface 122 decodes downstream data transport cells and provides communication with information sources 38, 40, 42. The digital interface 122 supports many different protocols of exchange as PCI bus, ISA bus, or any other suitable technology that provides input/output capability to the information

source. The frame synchronizer **110** produces downstream and upstream symbol clocks from the downstream signal, detects the frame synchronization word **88** and control word **89** transmitted by central office **30**.

Frame synchronizer **110** is connected to frame control circuit **112** that changes transmit frame structure in accordance with FIG.2, FIG.3, FIG.4 depending on the received control word **89**. Frame control circuit **112** turns on/off the Downstream amplifier **102** and Upstream amplifier **106** depending on the current operation mode and transmits corresponding control signals to downstream repeater **44**, using control line **134** connected to the middle point of the primary winding of transformer **100**.

Upstream data is routed from one of the information source lines **128,130,132** to digital interface block **122** which converts the upstream data to transport cells **90**. Acknowledge generator **118** adds to transport cells' data acknowledge word **92**. The upstream binary data is converted to QAM line symbols by QAM modulator **104**, which is connected to upstream amplifier **102**. Upstream amplifier **102** transmits upstream QAM line signal to twisted pair **26**.

Communication system **20** may service simultaneously many different home modems **36** from the simplest Home modem GRADE.1 to most complex Home Modem Grade 4. Frame synchronizer **110** of complex home modem is connected to QAM modulator **104** by control line **103** and to QAM demodulator **108** by control line **107**. QAM modulator **104** and QAM demodulator **108**, both supporting QAM4 or QAM16 or QAM64 or QAM256 modulation, according with current control word **89**, received by synchronizer **110**.

FIG.10 illustrates in details a downstream repeater **44**. Downstream Repeater **44** includes local transformer **200** that is coupled to local data line **26** to downstream amplifier **206** and to upstream buffer **208**. A middle point of the primary winding of transformer **200** is coupled by control line **218** to frame control circuit **210**. The frame control circuit **210** is connected to the enable input **214** of upstream buffer **208** and to the enable input **216** of downstream amplifier **206**. Low Pass Filter **202** is connected to local phone line **28** and to



line transformer **204**. Line transformer **204** is coupled to the output of upstream buffer **208**, to the input of downstream amplifier **206** and to the twisted pair subscriber line **32**. The frame control circuit **210** switches on/off the downstream amplifier **206** and upstream buffer **208**, in accordance with the signal on control line **218**. This frame control signal comes from the Home modem by local data line **26**.

FIG. 11 illustrates in details a line repeater **45**. The line repeater **45** includes first a transformer **150** that is connected to twisted pair **29** that routed from the subscriber, to low pass filter **152**, to the input of upstream amplifier **154** and to the output of downstream amplifier **156**. A second transformer **158** is connected to twisted pair **31** that is routed from the central office, to low pass filter **152**, to the output of upstream amplifier **154** and to the input of downstream amplifier **156**. A QAM demodulator **160** is coupled to the second transformer **158** and to frame synchronizer **162**. A frame control circuit **164** is coupled to frame synchronizer **162**, to enable input **166** of upstream amplifier **154** and to enable input **168** of downstream amplifier **156**. QAM demodulator **160** converts a downstream signal received from twisted pair **31**. The binary sequence of decoded downstream data is transmitted to frame synchronizer **162**.

The frame synchronizer **162** produces the downstream and upstream symbol clocks, detects the frame synchronization word **88** and the control word **89**, transmitted by central office **30**.

Frame synchronizer **162** is connected to frame control circuit **164** that changes the transmission frame structure in accordance with FIG.2, FIG.3, FIG.4 depending on the received control word **89**. Frame control circuit **164** turns on/off the Downstream amplifier **156** and Upstream amplifier **154**, depending on the current operation mode.

FIG. 12 illustrates in details an upstream repeater **46**. The upstream repeater **46** includes line transformer **250** that is connected to subscriber line **32**, low pass filter **252**, that is connected to line transformer **250** and to phone

line 48, upstream amplifier 254, that is connected to line transformer 250 and to upstream data line 52, downstream buffer 256, that is connected to line transformer 250 and to downstream data line 50 and frame control circuit 258, that is connected to enable input 260 of upstream amplifier 254, to enable input 262 of downstream buffer 256 and to control line 51. The frame control block 258 switches on/off the downstream buffer 256 and upstream amplifier 254, in accordance with the frame control signal that transmits from office modem 58 through concentrator 56.

FIG.13 illustrates in details Office Modem 58. Office Modem 58 includes upstream amplifier 300 that is connected to up data line 52 and downstream amplifier 302 that is connected to down data line 50. A frame control circuit 304 is coupled to enable input 306 of upstream amplifier 300, to enable input 308 of downstream amplifier 302 and to control line 51. The output of upstream amplifier 300 is connected to the input of QAM demodulator 310 and to the input of downstream amplifier 302, which is connected to the output of QAM modulator 312. The output of QAM demodulator 310 is connected to synchronizer 322, to bit rate adapter 328, and to acknowledge receiver 316. The acknowledge receiver 316 is connected to frame processor 314 and to the decoder of home modem type 318. Frame processor 314 is coupled to the synchronization word generator 330, control word generator 332 and to frame control circuits 304. Frame processor 314 is connected to central office concentrator 56 using service line 86. Synchronization word generator 330 and control word generator 332 are coupled to QAM modulator 312.

Bit rate adapter 328 is coupled to QAM modulator 312, to QAM demodulator 310 and to digital interface 320. Digital interface 320 is coupled to network device 72 using network data line 76. Oscillator 315 is coupled to frame processor 314 and provides the downstream clock.

The upstream signal received from twisted pair 52 is converted by QAM demodulator 310. The binary sequence of the decoded upstream data is

transmitted to acknowledge receiver **316** , to synchronizer **322** and to bit rate adapter **328**.

The bit rate adapter **328** decodes received upstream data transport cells **90** and transmits binary data to digital interface **320**. The digital interface **320** provides communication with network device **72**. The digital interface **320** supports many different protocols of exchange as PCI bus, ISA bus, or any other suitable technology that provides input/output capability to data network. The synchronizer **322** produces upstream symbol clocks from the received upstream signal.

Acknowledge receiver **316** decodes acknowledges **92**, issued from home modem **36** and transmits them to the decoder of home modem type **320** and to frame processor **314**.

The decoder of home modem type **318** analyzes received acknowledge and fix information about characteristics of home modem **36** that is connected to office modem **58** in current time. According to this information, the decoder of home modem type **318** switches bit rate adapter **328** , QAM modulator **312** and QAM demodulator **310** to support corresponding level of modulation : QAM4 or QAM16 or QAM64 or QAM256 and corresponding upstream and downstream data bit rate.

The frame processor **314** provides control signals for synchronization word generator **330**, control word generator **332** and for frame control circuit **304**. The frame processor **314** analyzes acknowledges **92** that are send by home modem **36** and changes the transmission frame structure as shown in FIG.2, FIG.3, FIG.4.

Actually the frame structure depends on the information source type connected to home modem **36** in the current communication session.

The frame control circuit **304** switches on/off downstream amplifier **302** and upstream amplifier **300**, in accordance with commands issued from frame processor **314** and provides upstream repeater frame control signal on control line **51**.

FIG.14 is a flow chart that illustrates the operation of SADSL communication system 20 in one embodiment of the present invention. In turn on concentrator 56, home modems 36 and office modems 58 are in standby state 400. The concentrator 56 is waiting for an activity of hook-off detector's . Upon detecting a need for data service 401, concentrator 56 selects 402, 403 an active subscriber 22 and an available office modem 58. Concentrator 56 switches directly its internal relays to make appropriate coupling 404 between subscriber and selected office modem 58.

Upon establishing of a coupling, the concentrator 56 sends wake up signal 405 to selected office modem 58 and transfers office modem 58 to initialization state 411 . In this state office modem 58 begins to operate and sends to home modem 36 sequences of initialization transmission frames 412, corresponding to symmetrical operation mode (FIG.4). Initialization transmission frames include synchronization word 88, initialization control word, and idle data transport cells 90. Idle transport cells include special sequence of QAM or DMT test symbols.

Home modem 36 in standby state 400 is waiting for downstream signal 423 and its frame control circuit 112 switches on downstream amplifier 106 of home modem 36 and downstream amplifier 206 of downstream repeater 44. During the initialization procedure, synchronizer 162 of home modem 36 trims downstream and upstream clocks of the home modem to synchronize transmission frames of office modem and home modem 424. After the completion of the synchronization process 425, home modem 36 switches to symmetrical mode operation (FIG.4 ) and sends to the office a "synchronization OK " acknowledge 426. Upon decoding this acknowledge 413, office modems 58 switch to "type of home modem detecting" study 414. In this study office modem 58 sends a request to home modem 36 and receives "modem type " acknowledge 427 . The type of home modem decoder 326 analyzes received acknowledge and switches QAM modulator 312 and QAM demodulator 310 of office modem 58, corresponding with the type of home modem 36 that is

connected to office modem **58** in the current communication cycle. At the same time, decoder **326** switches bit rate adapter **328** characteristics to adapt the bit rate of home modem **36** and office modem **58**. Next study of the initialization process is trimming **428**. It starts upon receiving from central office "trimming start" **415** of control word **89**. In this study are trimmed the gain and the frequency characteristics of downstream amplifier **106** of home modem **36** and upstream amplifier **300** of office modem **58**, using QAM or DMT test symbols. Upon completion of the trimming process, home modem **36** sends to the office modem "trimming OK" acknowledge **429**. Upon receiving "trimming OK" acknowledge **416**, office modem **58**, sends to the home modem the "start" control word **417**. In accordance with this command, home modem **36** turns on the information source analyzer **120** that checks which information source (symmetrical, half-asymmetrical or asymmetrical) is waiting for data access. Corresponding to the "source type", acknowledge word **92** is send to office modem **430**. In accordance with received "source type acknowledge", office modem **58** generates **418**, corresponding to "transmission frame control word" **89**. After receiving "transmission frame control word" **89**, every device that is connected to the subscriber line (office modem, home modem, repeaters) changes its transmission frame structure that is produced by frame control circuits, starting from next frame **431**. Upon change of the frame structure, office modem sends "access enable " control word **419**. Next study is an information exchange between subscriber information source and network device **420**. After the communication exchange is complete **407**, concentrator **56** sends to office modem **58** the stop command **408**, office modem **58** sends to home modem **36** the "stop control word" **421**, home modem **36** returns "stop acknowledge" **432** and home modem turns to the standby state **400**. Office modem **58** informs concentrator **56** that the communication session is ended **422**. Concentrator puts office modem in standby state **409** and disconnects office modem from corresponding upstream repeater **410**.

Fig.15 illustrates a communication system **500** that provides simultaneously telephone, DSL and Home Network service to subscriber **22**. A subscriber **22** is coupled to Central Office **30** using twisted pair subscriber line **32**. Subscriber line **32** supports simultaneously telephone and data service between Central Office **30** and subscriber **22**. Subscriber **22** includes a telephone **34** and a number of home modems **505**. Telephone **34** is coupled to twisted pair subscriber line **32** by Low pass filter **501**, that reduces noise in the voice bandwidth. Several home modems **505** are directly connected to subscriber line **32**. Every home modem **505** transmits and receives data using QAM or DMT modulation signals. Every home modem **505** is coupled with information source **40** that may be symmetrical, half-asymmetrical or asymmetrical. Home modems **505** connected to the same subscriber line may be of different types and may support one or several levels of line signals as described above. Every home modem **505** may be connected to Central Office **30** or to another home modem **505**. Control of communication process is provided by Office modem **509** connected to subscriber line **32** in current communication cycle. Communication system **500** depicted in Fig.15 uses the same method as the communication system shown in Fig.1, but uses more complex transmit framing. This framing comprises super frame structure, that includes a number of transmit frames. Each of the transmit frames can be used independently for communication between different home modems with an office modem or another home modem.

FIG.16 illustrates in more details home modem **505**.

The home modem **505** includes line transformer **100** connected to twisted pair **32**, upstream amplifier **102** that is coupled to transformer **100** and to QAM modulator **104**, downstream amplifier **106** which is coupled to transformer **100** and to QAM demodulator **108**, frame synchronizer **110** coupled to QAM demodulator **108** and to frame control circuit **112**, digital interface **122** coupled to QAM modulator **104** and to QAM demodulator **108**, and information source analyzer **120** coupled to acknowledge generator **118**. Information source

analyzer 120 and digital interface 122 are coupled by digital line 128 to symmetrical information source 38, by digital line 130 to half asymmetrical information source 40, by digital line 132 to asymmetrical information source 42. Acknowledge generator 118 is coupled to QAM modulator 104. Superframe synchronizer 506 is coupled to frame synchronizer 110 and to superframe control circuit 504, that connected to frame control circuit 112.

FIG.17 illustrates in details Office Modem 509. Office Modem 509 includes upstream amplifier 300 that is connected to up data line 52 and downstream amplifier 302 that is connected to down data line 50. A frame control circuit 304 is coupled to enable input 306 of upstream amplifier 300, to enable input 308 of downstream amplifier 302 and to control line 51. The output of upstream amplifier 300 is connected to the input of QAM demodulator 310 and the input of downstream amplifier 302 is connected to the output of QAM modulator 312. The output of QAM demodulator 310 is connected to synchronizer 322, to bit rate adapter 328, and to acknowledge receiver 316. The acknowledges receiver 316 is connected to frame processor 314 and to the decoder of home modem type 318. Frame processor 314 is coupled to synchronization word generator 330, control word generator 332 and to frame control circuits 304. Frame processor 314 is connected to central office concentrator 56, using service line 86. Synchronization word generator 330 and control word generator 332 are coupled to QAM modulator 312. Bit rate adapter 328 is coupled to QAM modulator 312, to QAM demodulator 310 and to digital interface 320. Digital interface 320 is coupled to network device 72 using network data line 76. Oscillator 315 is coupled to frame processor 314 and provides the downstream clock. Superframe synchronizer 517 is coupled to frame processor 334 and to superframe control circuits 519 that is coupled to frame control circuits 519. Office modem 509 includes initialization processor 521 that produces control of every block of office modem 509 at the beginning of the communication session.

Fig.18 illustrates the superframe structure. Superframe **503** includes the four transmission frames **80**, described above. Transmission frame **80** has a constant of 4 ms duration and includes Downstream Interval **82**, Upstream Interval **84** and Gap Interval **86**. Downstream Interval **82** includes synchronization word (SW) **88**, control word (CW) **89** and following data transport cells (DTC) **90** that contain downstream data. Upstream Interval **84** include acknowledges (AK) **92** and following data transport cells (DTC) **90** that contain upstream data. Gap Interval (GI) **86** is the guard time for the next transmission frame. Transmission frame 0 has a different synchronization word (SF SW) **502** and is used for superframe synchronization. The superframe has a constant of 16 ms duration. Every transmission frame **80** of superframe **503** can be used independently for communication between Office modem **509** and up to 4 active home modems **505** or for communication between up to 8 home modems. In case of communication between home modems (home digital network), one transmission frame **80** services two home modems **505**. One of them transmits QAM or DMT signal during the downstream interval and receives QAM or DMT signal during the upstream interval. Another home modem **505** transmits QAM or DMT signal during the upstream interval and receives QAM or DMT signal during the downstream interval.

Fig 19 is a timing diagram of communication system **500** that provides simultaneously DSL and Home digital network service. Office modem **509** operates with superframe **503** and produces synchronization for home modem 1 (**505**), home modem 2 (**505**) and home modem 3 (**505**). Every home modem is connected to the same twisted pair on the subscriber end of the system. Communication system **500** provides DSL service to home modem 1 during Transmission frame 0 and transmission frame 1. During transmission frame 2 and transmission frame 3, communication system 500 provides home digital network service between home modem 2 and home modem 3.



Office modem **509** may be programmed for different assignation of transmission frames **80** to different home modems **505** of the subscriber. Programming of the office modem is performed by initialization of processor **521** at the beginning of the communication session. During this process the Office modem, may, for example, analyze the received signal for a detection of the active home modem and the kind of service that the active home modem needs, define which framing structure will be optimal and send to each active home modem information about assignments of this home modem operation mode and transmission frame. The Initialization process can be implemented in many versions and it is not detailed in this description of the present invention.

Fig.20 illustrates a communication system **600** that provides simultaneously digital telephone, DSL and Home Network services to subscriber **22**. A subscriber **22** is coupled to Central Office **30** using twisted pair subscriber line **32**. Subscriber line **32** supports simultaneously digital telephone and data service between Central Office **30** and subscriber **22**. Subscriber **22** includes a digital telephone set **601** and a number of home modems **505**. Digital Telephone Set **601** and several home modems **505** are directly connected to subscriber line **32**. Every home modem **505** transmits and receives data using QAM or DMT modulated signals. Digital Telephone set **601** transmits and receives voice signals in digital form (after PCM - pulse code modulation or ADM - adaptive delta modulation coding ) using QAM or DMT line signals. In case of the QAM modulation, voice signals and dialing signals are transmitted during part of the time assigned for synchronization and control signals in the downstream interval and part of time assigned for the acknowledgment in the upstream interval. In case of the DMT modulation, dialing signals is transmitted in the same way but the voice signal transmits in during data downstream and upstream interval on low frequency carriers. Central office **30** of communication system **600** includes PCM or ADM codec **603** connected to office modem **509** and to frame relay **605** of POTS.

Fig. 21 illustrates time structure of the transmission frame in the communication system that provides digital telephone service. Upstream and downstream intervals of the transmission frame **80** include telephone code words (V) **607**. The telephone code word is used for transmission of voice and dialing signals.

Fig.22 illustrates in more details the Digital Telephone Set in the QAM application. The digital telephone set **601** includes line transformer **100** connected to twisted pair **32**, upstream amplifier **102** that is coupled to transformer **100** and to QAM modulator **104**, downstream amplifier **106** which is coupled to transformer **100** and to QAM demodulator **108**, frame synchronizer **110** coupled to QAM demodulator **108** and to frame control circuit **112**, PCM coder **611** coupled to QAM modulator **104** and PCM decoder **613** coupled to QAM demodulator **108**. A microphone **615** is coupled to the input of PCM coder **611**. A telephone **617** is coupled to the output of PCM decoder **613**. Dialing and signaling controller **619** is coupled to QAM modulator **104**, QAM demodulator **108**, Frame synchronizer and to dialing keyboard **621**. Power supply **623** is activated only during the hook-off telephone state and supplies power to every block of the digital telephone set **601**. Power supply **623** sources by Central Office like existing analog telephone apparatus. At present, many companies manufacture CMOS integral circuits of PCM codec **625** that includes PCM coder **611** and PCM decoder **613**???. These are very cheap and micropower devices. Frame synchronizer **110**, QAM modulator **104**, QAM demodulator **108**, Frame control circuits **112**, Dialing and signaling controller **619** can be implemented by means of CMOS ASIC technology. Finally digital telephone set **601** may comprise only one CMOS IC, that provides all necessary functions for digital voice communication.

## INDUSTRIAL APPLICABILITY

The implementation of the present invention is very easy. The SOURCE ADAPTIVE DIGITAL SUBSCRIBER LINE can be implemented on basis of the existing ADSL system. Nowadays the technology of ADSL with DMT signals is well known and many worldwide semiconductor companies like TEXAS INSTRUMENT, ANALOG DEVICES, SIEMENS manufacture chip sets for DMT signals processing and analog Front End chips for ADSL (LINEAR TECHNOLOGY, TI, ALCATEL, ANALOG DEVICES ). Most of the digital chips for DMT processing include DSP that may be programmed to work according to the present method. SADSLS is fully compatible with existing ADSL in the frequency band and transmitted levels. That means that SADSLS and existing ADSL can work within the same cable without problems. Moreover, it is possible to design a universal OFFICE MODEM that can work with an SADSLS or ADSL HOME MODEM. The simplest SADSLS modem can be included within the TV set, VIDEO PHONE, HF AUDIO SYSTEM and works on the same subscriber line that is connected to the ADSL modem, included into the personal computer. From another point of view, using of repeaters can provide an advantage for SADSLS in long distance subscriber lines.

Although the present invention has been described within the framework of several embodiments, a myriad of changes, variations, alterations and modifications may be suggested by one skilled in the art, and it is intended that the present invention encompasses such changes, variations, alterations and modifications that suit the spirit and scope of the claims detailed hereafter.

## CLAIMS

What is claimed is :

1. A digital subscriber line communication system on telephone cable, comprising :

A plurality of asymmetrical information sources. These receive high bit rate downstream data and produce only output control signals with a very low bit rate, located at a plurality of the subscriber premises;

A plurality of half-symmetrical information sources. These receive high bit rate downstream data and produce upstream data with low bit rate, located at a plurality of the subscriber premises;

A plurality of symmetrical information sources. These have the same middle bit rate upstream data and downstream data, located at a plurality of the subscriber premises;

A plurality of different home modems, located at a plurality of the subscriber premises and coupled to a number of different information sources, located at the same subscriber. Every home modem has a frame synchronizer, an information source analyzer, an acknowledge generator and a frame control circuit that changes the transmission frame of the home modem in accordance with the type of information source connected to the home modem in the current transmit cycle;

A plurality of twisted pair subscriber lines coupled to a plurality of home modems, each twisted pair subscriber line forming a local loop;

A central office coupled to a plurality of twisted pair subscriber lines. The central office includes a number of office modems. These may operate with any home modem and are coupled through a concentrator to a plurality of subscriber lines. Each office modem includes a frame synchronizer, a acknowledges receiver, an analyzer of home modem type, a frame control circuit and a bit rate adapter. The office modem changes its transmission frame structure and upstream /downstream bit rate in accordance with the type of

home modem and the type of information source of the subscriber that is currently connected to this office modem.

2. The communication system of claim 1, further comprising:

A number of different home modems, located at the subscriber premises, connected to the same twisted pair subscriber line and coupled to number of different information sources. Every home modem has a superframe synchronizer and a superframe control circuit that assigns a different transmission frame for different home modems, in accordance with the control signals received from the office modem.

A number of office modems located at the central office. Each office modem includes a superframe synchronizer, a superframe control circuit and an initialization processor. The office modem assigns during the initialization process different transmission frames of the transmission superframe for different home modems connected to the same twisted pair at the subscriber end. The initialization process produced by the initialization processor of the office modem in the beginning of every communication session.

3. The communication system of claim 1, further comprise:

A number of home modems, located at the subscriber premises, connected to the same twisted pair subscriber line and coupled to a number of different information sources. Every home modem can be programmed by the office modem for communication with an office modem or for communication with another home modem coupled to the same twisted pair subscriber line.

A number of office modems located at the central office. Each office modem includes a superframe synchronizer, a superframe control circuit and an initialization processor. The office modem assigns during the initialization process, one or several transmission frames of the transmission superframe for communication home modems with the office modem and different transmission frames for communication of home modems with each other connected to the same twisted pair on subscriber end. The initialization process is performed by the initialization processor of the office modem in the beginning of every communication session.

4. The communication system of claim 1, further comprise:

A number of home modems, located at the subscriber premises, connected to the same twisted pair subscriber line and coupled to number of different information sources.

A digital telephone set located at the subscriber premises, connected to the same twisted pair subscriber line. A digital telephone set including a frame synchronizer, PCM or ADM codec and a dialing and signaling circuit.

A number of office modems located at the central office. Each office modem has a PCM or ADM codec, a dialing and signaling circuit and a frame synchronizer.

5. The communication system of claim 1, further comprising a local server which is located on the subscriber end of a plurality of twisted pair subscriber lines routed to a building or telephone box.

The local server includes a plurality of downstream repeaters, which are coupled to twisted pair subscriber lines. Each downstream repeater amplifies the downstream signal and splits the twisted pair subscriber line into a twisted pair data line and a twisted or flat pair phone line.

6. The communication system of claim 2, further comprises a local server with downstream repeaters. Each downstream repeater includes a downstream amplifier, an upstream buffer and a frame control circuit that is coupled to a home modem by a twisted pair data line.

7. The communication system of claim 1, further comprise a central office that includes a plurality of upstream repeaters coupled to twisted pair subscriber lines. Each upstream repeater amplifies the upstream signal and splits the twisted pair subscriber line into a downstream data line, upstream data line and a twisted or flat pair phone line.

8. The communication system of claim 4, further comprises a central office with upstream repeaters. Each upstream repeater includes an upstream amplifier, a downstream buffer and a frame control circuit that is coupled to the office modem by a concentrator.

9. The communication system of claim 1, further comprise a plurality of line repeaters coupled to twisted pair subscriber lines. Each line repeater includes a frame synchronizer, a downstream amplifier, an upstream amplifier and a frame control circuit that is coupled to the frame synchronizer.

10. A method for transmitting and receiving downstream and upstream data using twisted pairs of telephone cables in digital subscriber line communication system, the method comprising :

Packing downstream data to data transport cells . Each data transport cell includes a fixed number of bits;

Conversion of data transport cells to downstream data blocks of QAM or DMT symbols, producing synchronization block of QAM symbols and a downstream control block of QAM symbols;

Sequential transmission of the synchronization block, the control block of QAM symbols, the downstream data blocks of QAM or DMT symbols with downstream bit rate during the downstream time interval of transmission frame having a fixed duration;

Packing of upstream data to data transport cells that include a fixed number of bits, converting data transport cells to upstream data blocks of QAM or DMT symbols, producing an upstream acknowledge block of QAM modulation symbols;

Sequential transmission of the upstream acknowledge block, upstream data blocks of QAM or DMT symbols during the upstream time interval of a transmission frame having a fixed duration. The upstream symbol rate is in several times less than the downstream symbol rate.

A method comprising changes of transmits frame structure depending on the type of information source that is connected to the subscriber line in the current communication session.

A method comprising generation of three different transmission frame structures with different duration of the downstream and upstream timing intervals: symmetrical structure that is corresponding to the same downstream and upstream data bit rate, half asymmetrical structure that is corresponding to

the high downstream data bit rate and low upstream data bit rate , asymmetrical structure that corresponds to very high downstream data bit rate and very low upstream data bit rate

11. The method of claim 10 further comprise:

Packing a number of transmission frames into a superframe, assigning transmission frames of a superframe to different communication channels;

Assigning to each communication channel two communication devices,

Sequential transmission of a number of transmission frames included into a superframe. Each transmission frame includes a synchronization block, a control block of QAM symbols, a downstream data from the first communication device and an upstream data from the second communication device assigned for this communication channel .

12. The method of claim 10 further comprise transmission of a synchronization word, of a control word and of an acknowledge word by symbols of QAM4 .

A method comprising transmitting of data transport cells with the same or different type of modulation. A method comprising changing of data transport cell modulation in accordance with the type of home modem that is connected to the subscribers line in the current communication cycle.

13. The method of claim 10 further comprises controlling of devices connected to a subscriber line (home modem, office modem, and repeaters) by the control word of a downstream line signal.

14. The method of claim 10 further comprises direct controlling of a downstream repeater from a home modem.

15. The method of claim 10 further comprises direct controlling of an upstream repeater from an office modem.



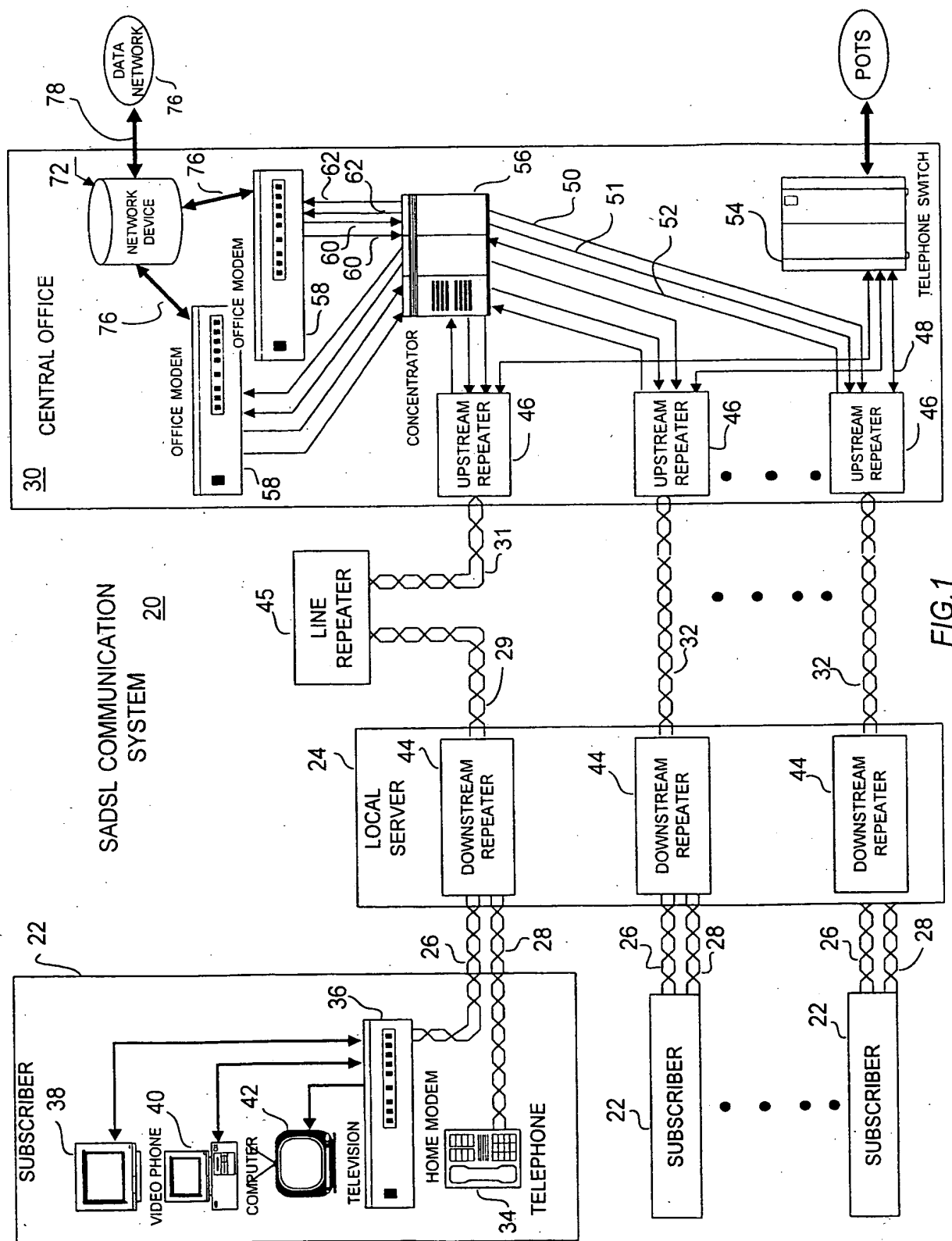


FIG.1

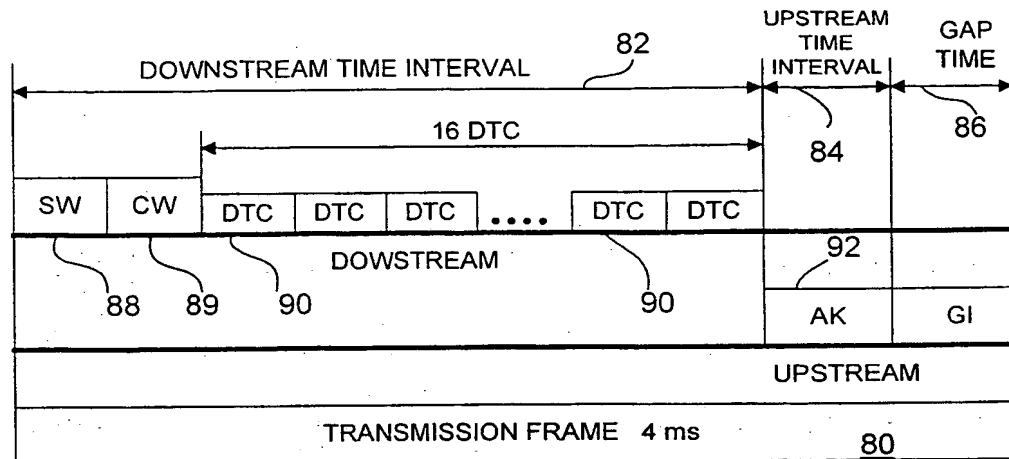


FIG. 2

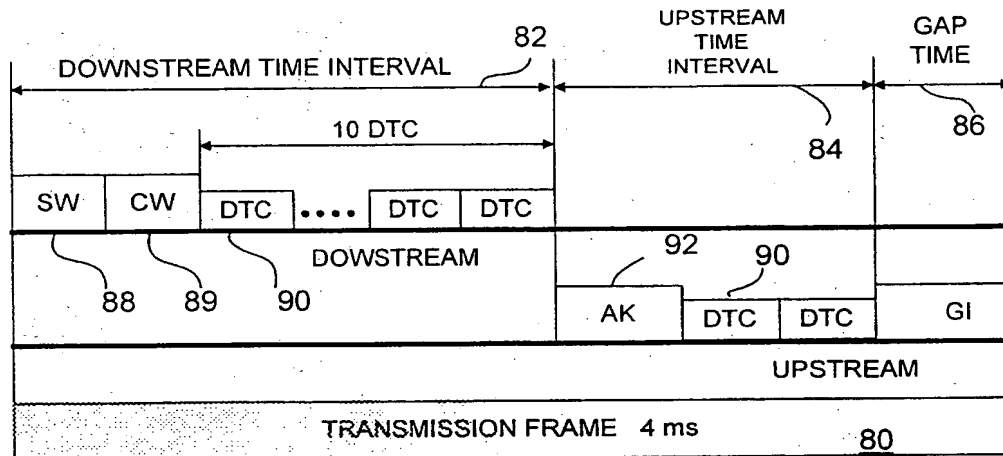


FIG. 3

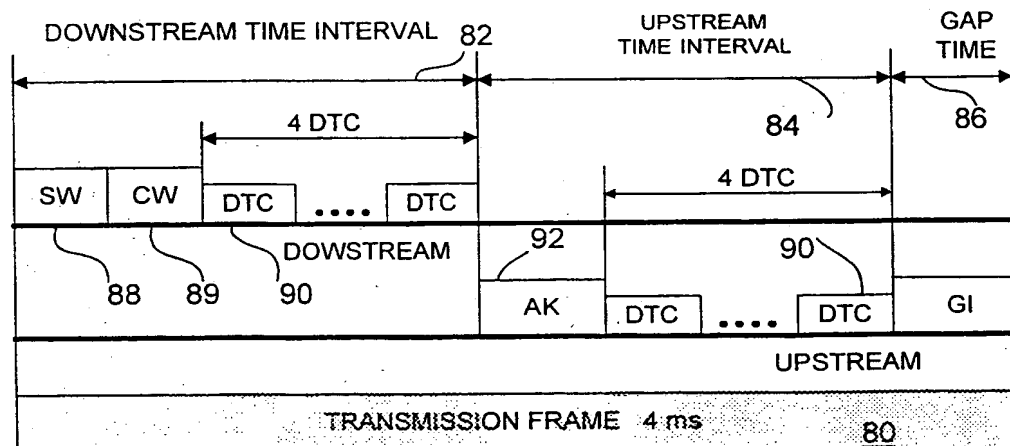


FIG. 4

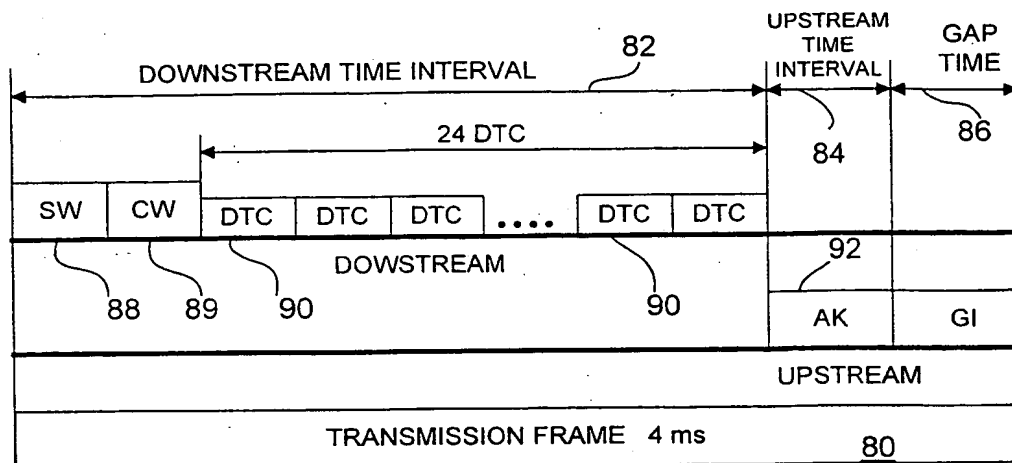


FIG. 6

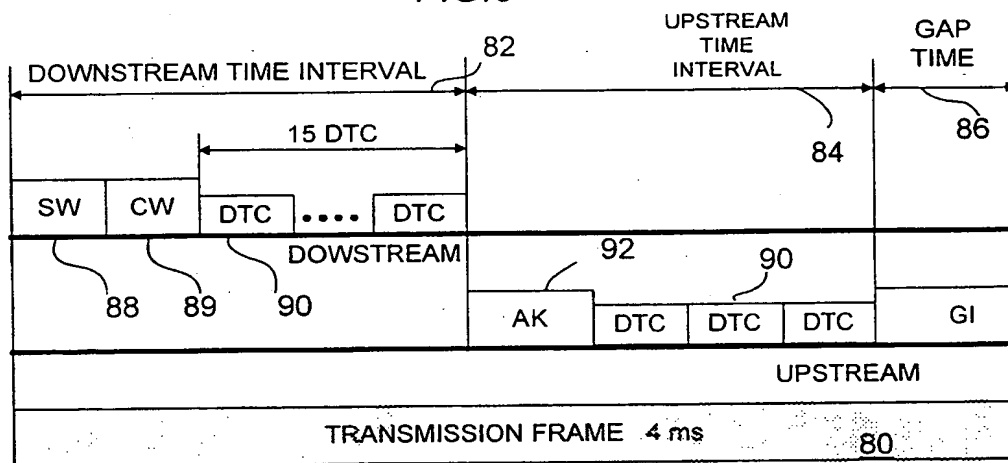


FIG. 7

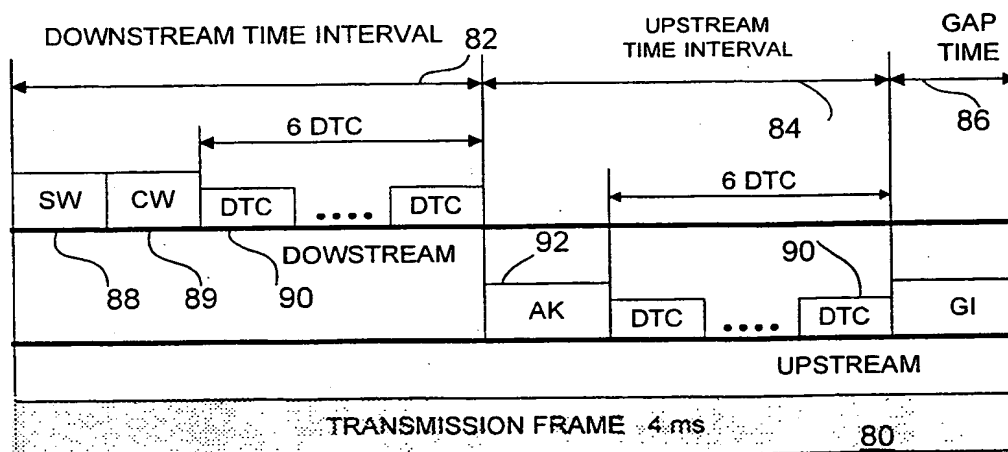


FIG. 8

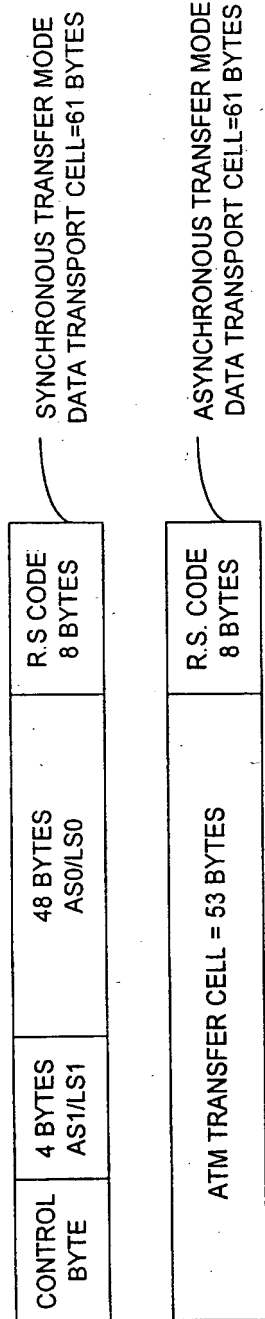
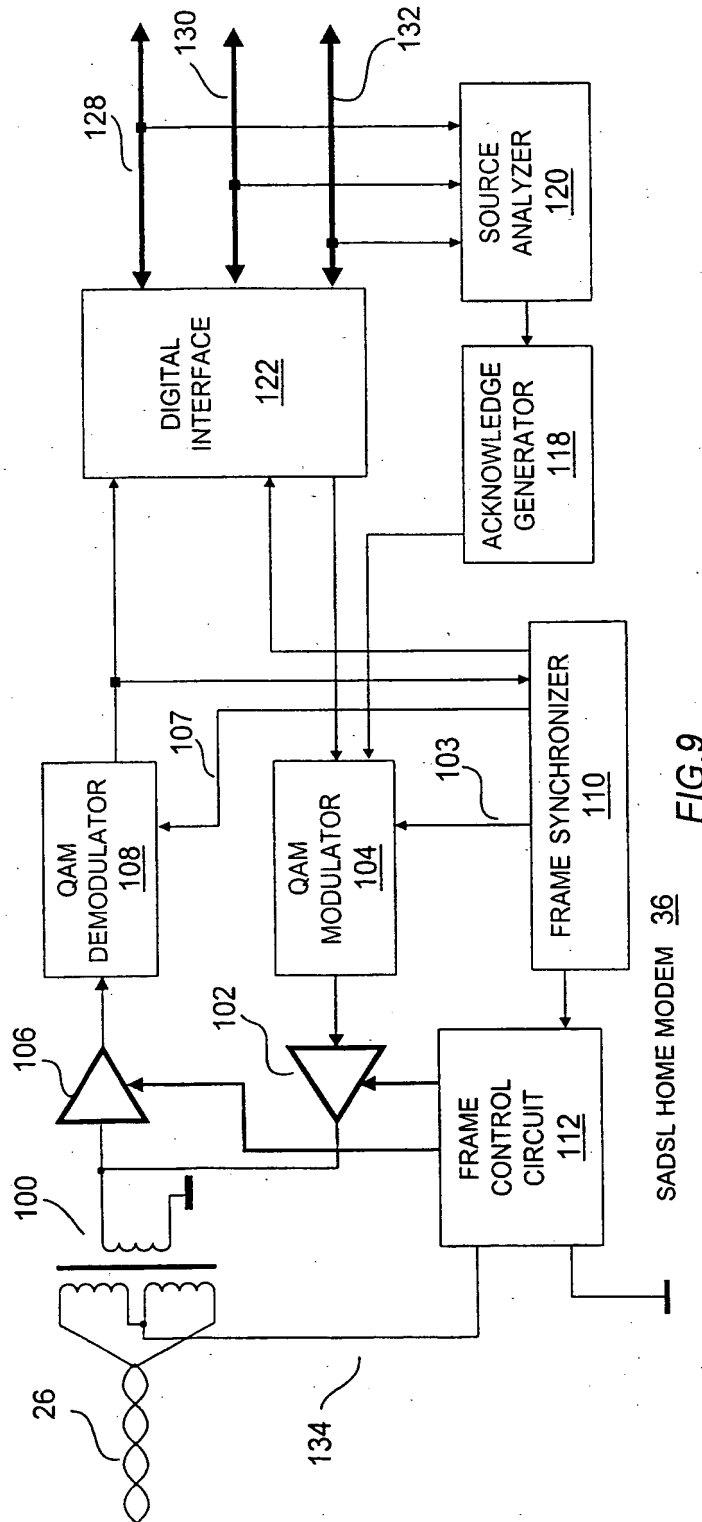


FIG. 5



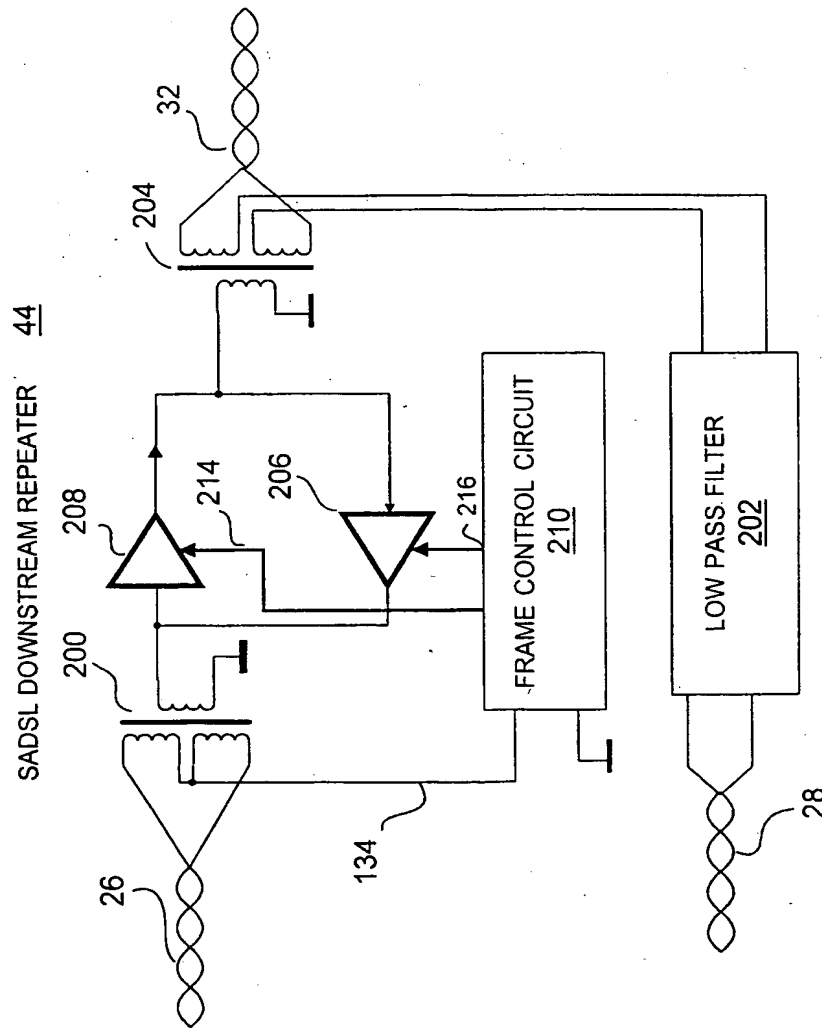


FIG.10

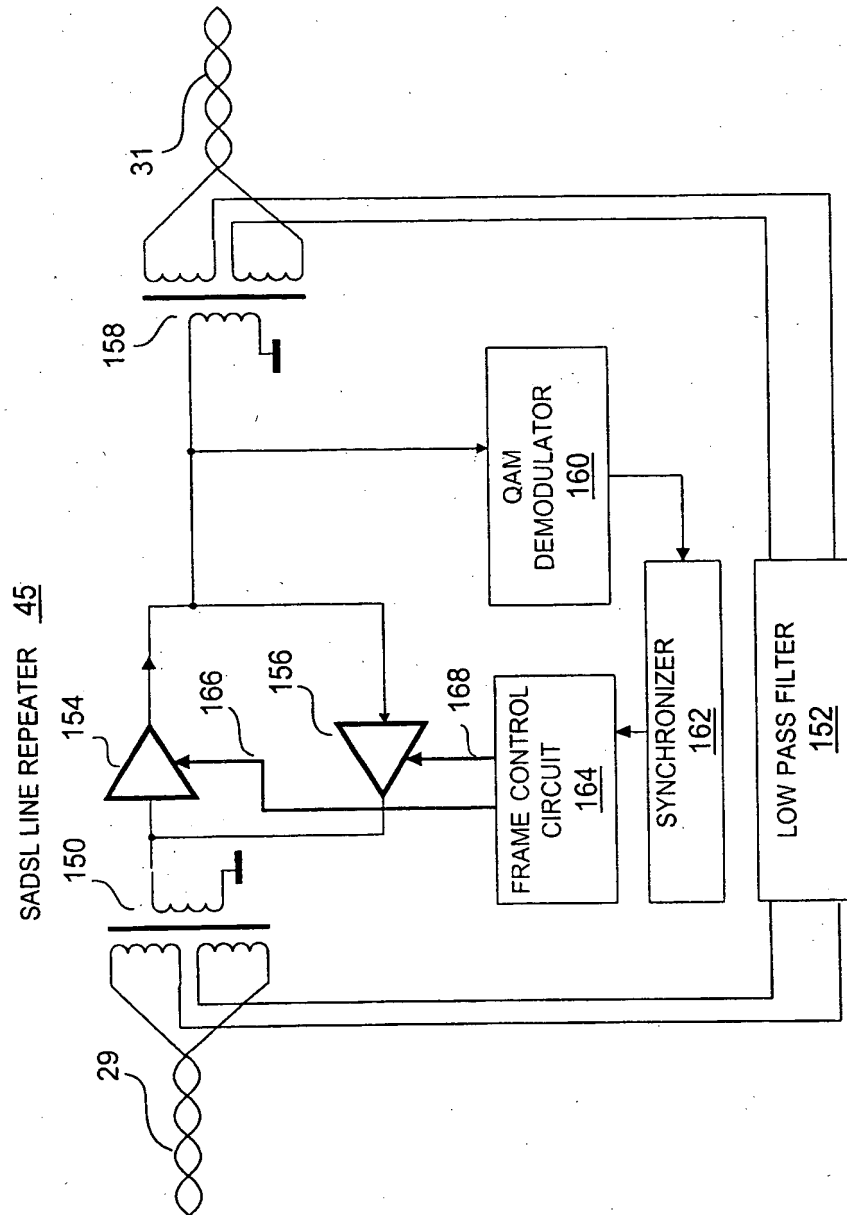


FIG.11

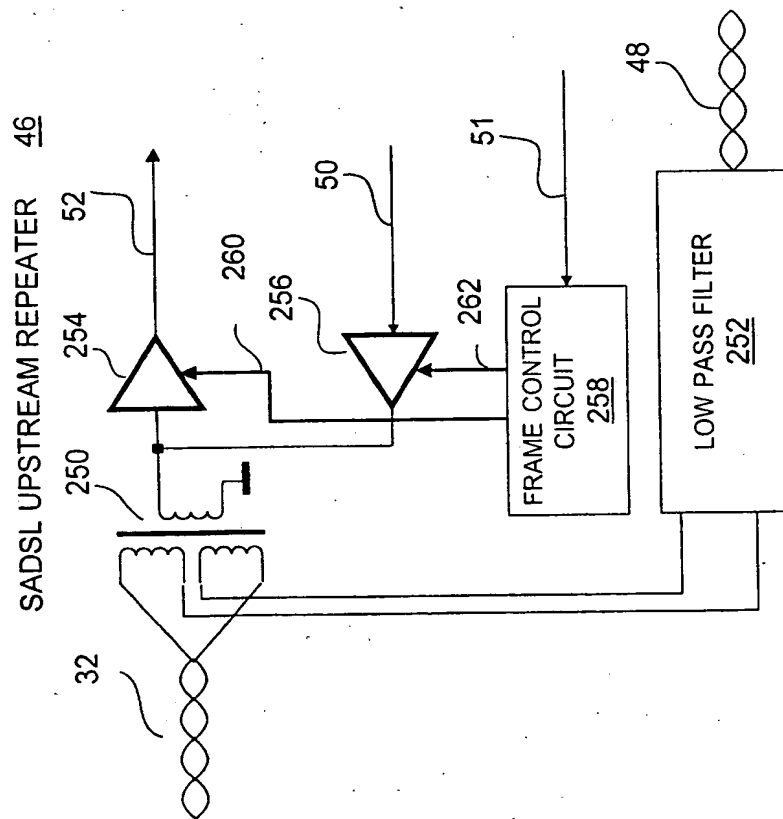
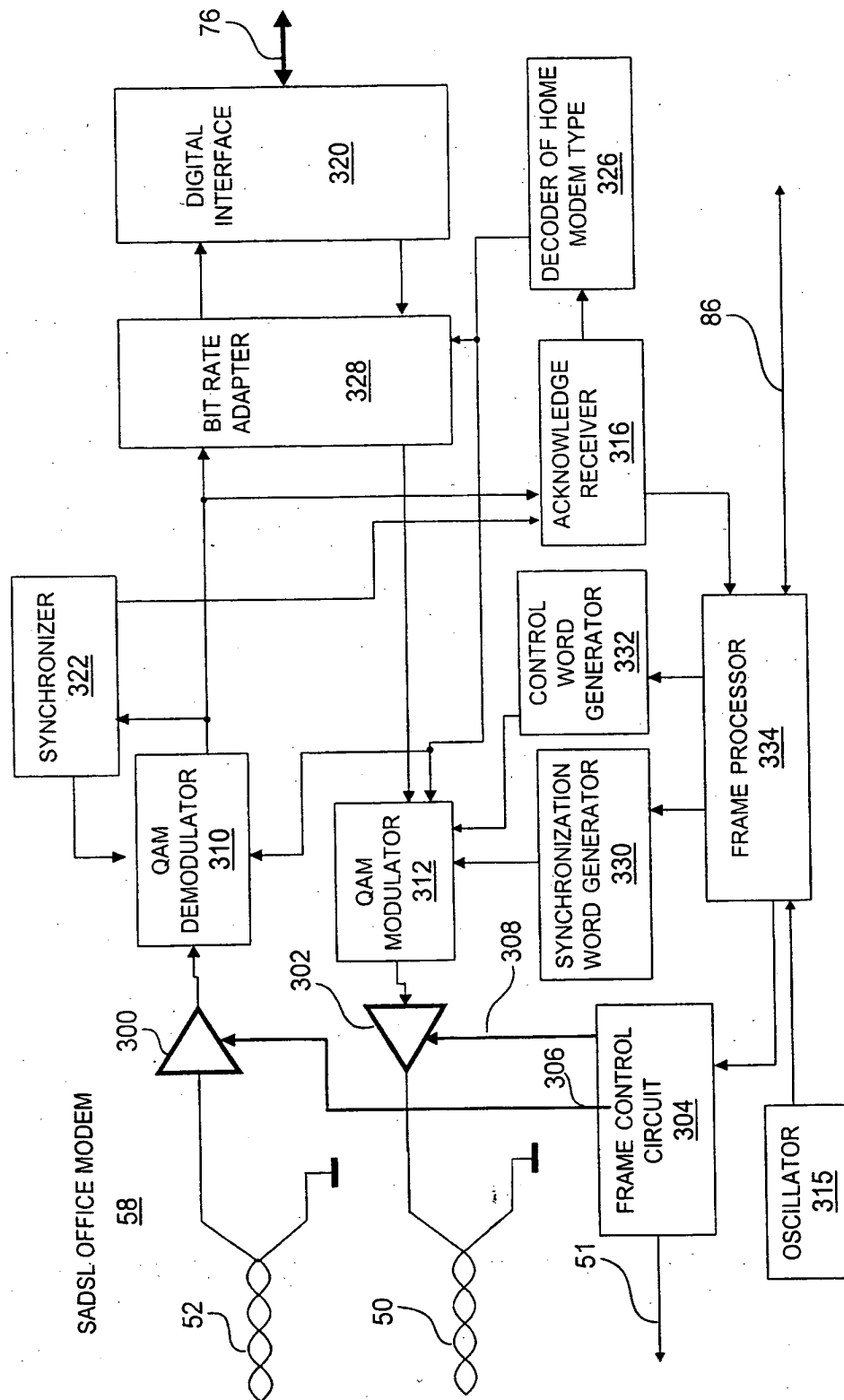


FIG.12



**FIG. 13**



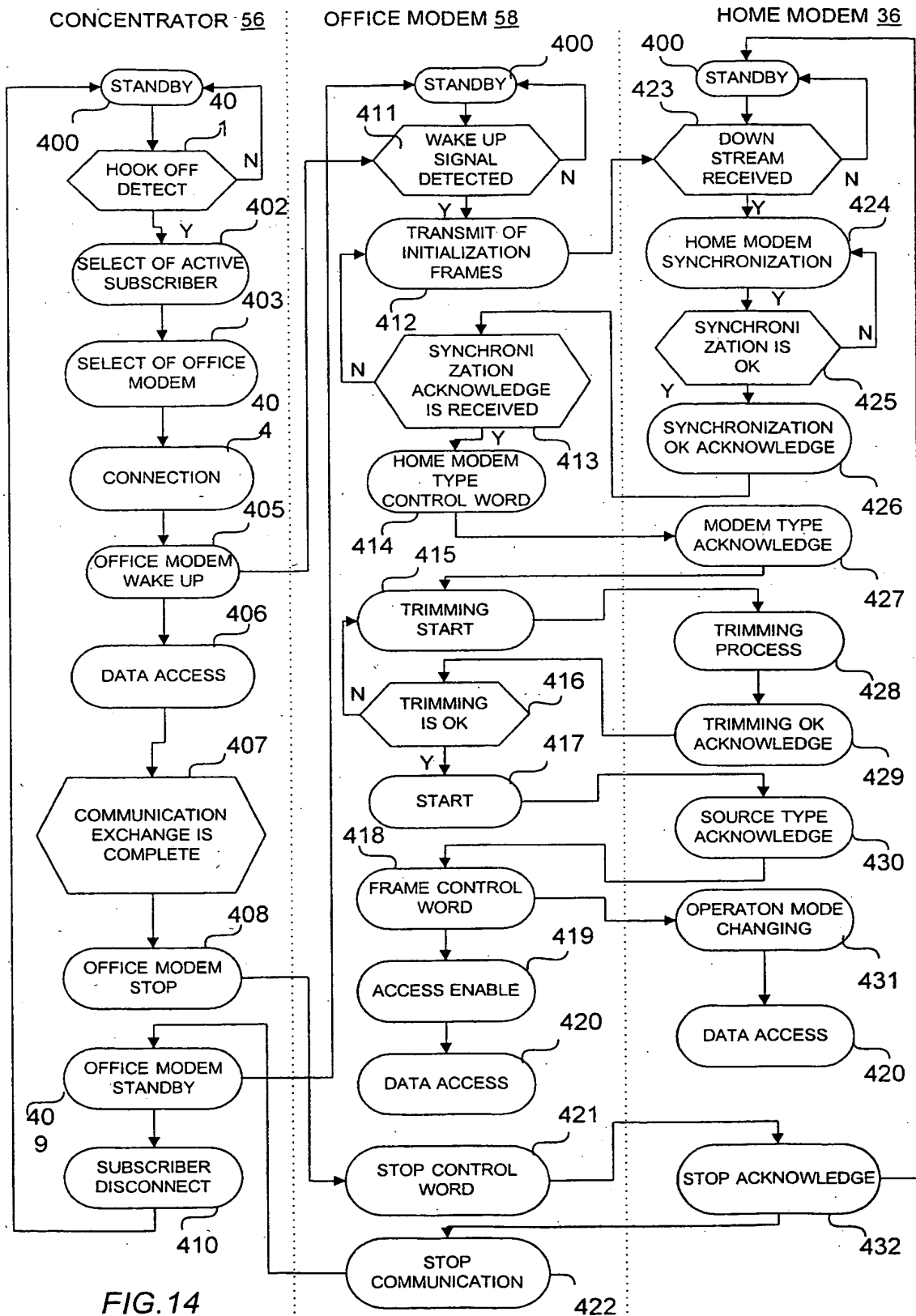
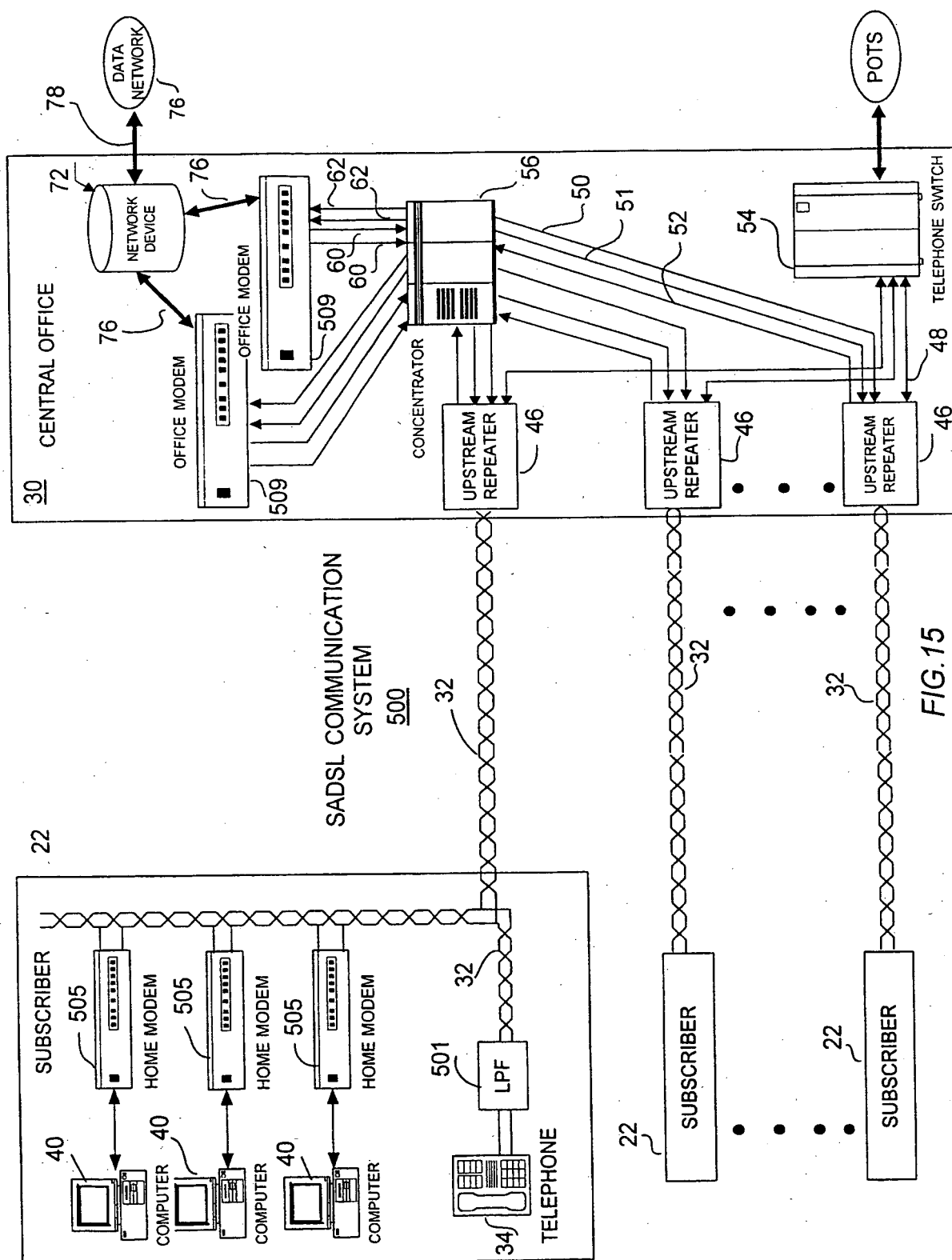
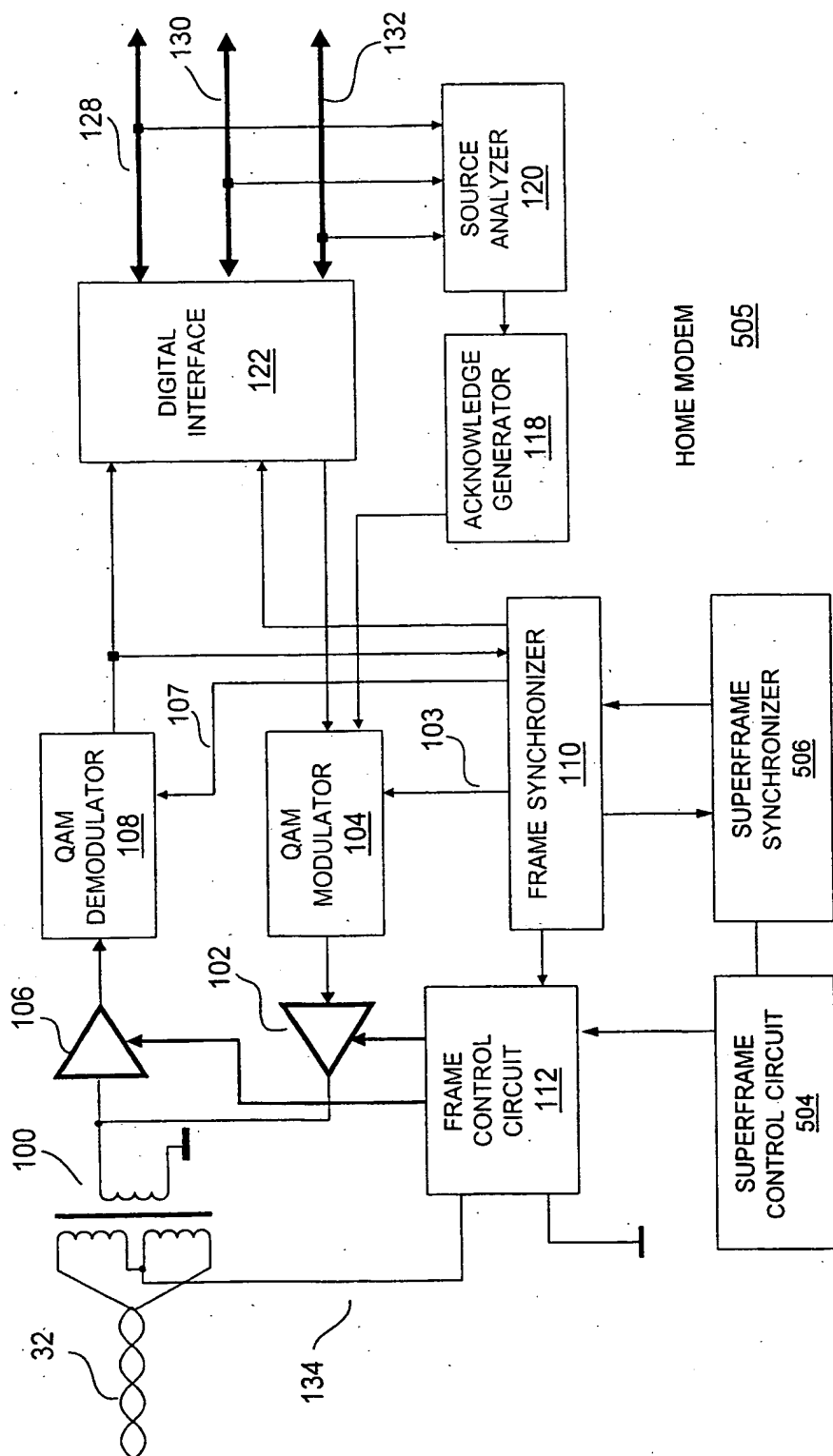


FIG. 14





**FIG. 16**

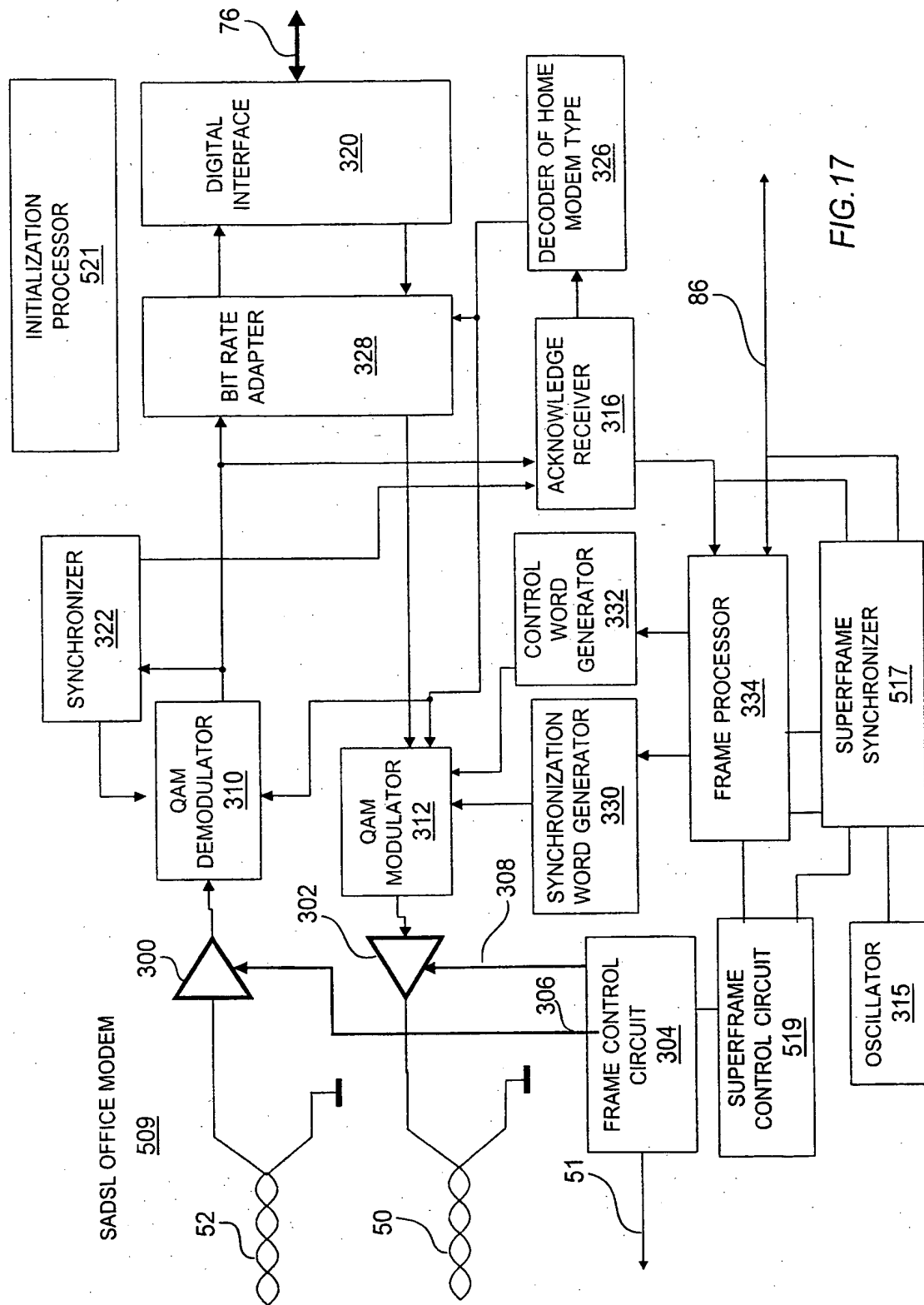


FIG. 17

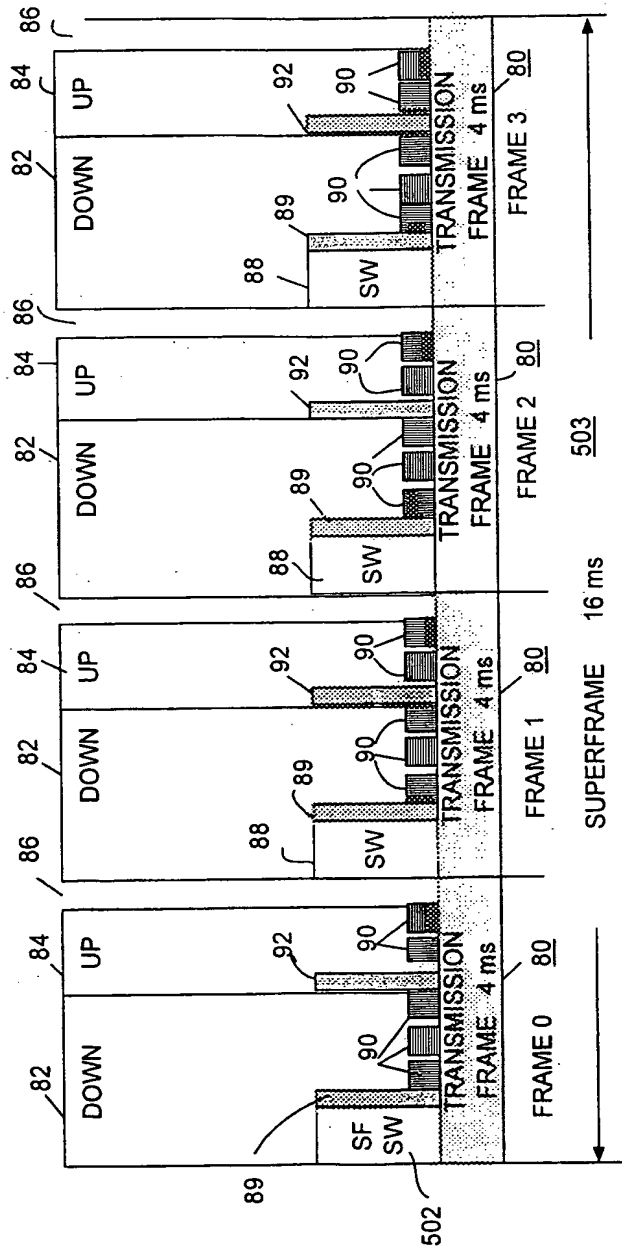


FIG.18

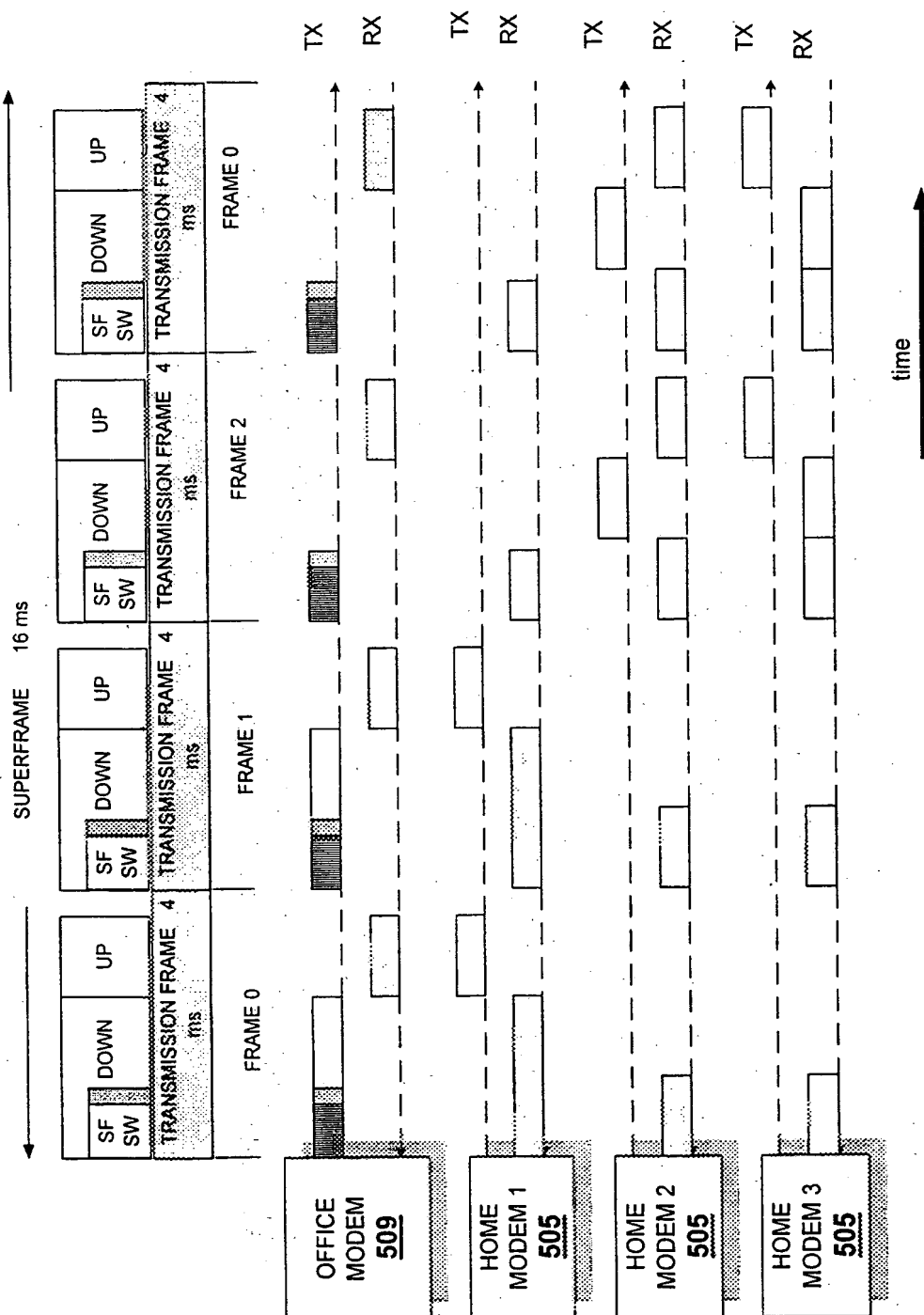
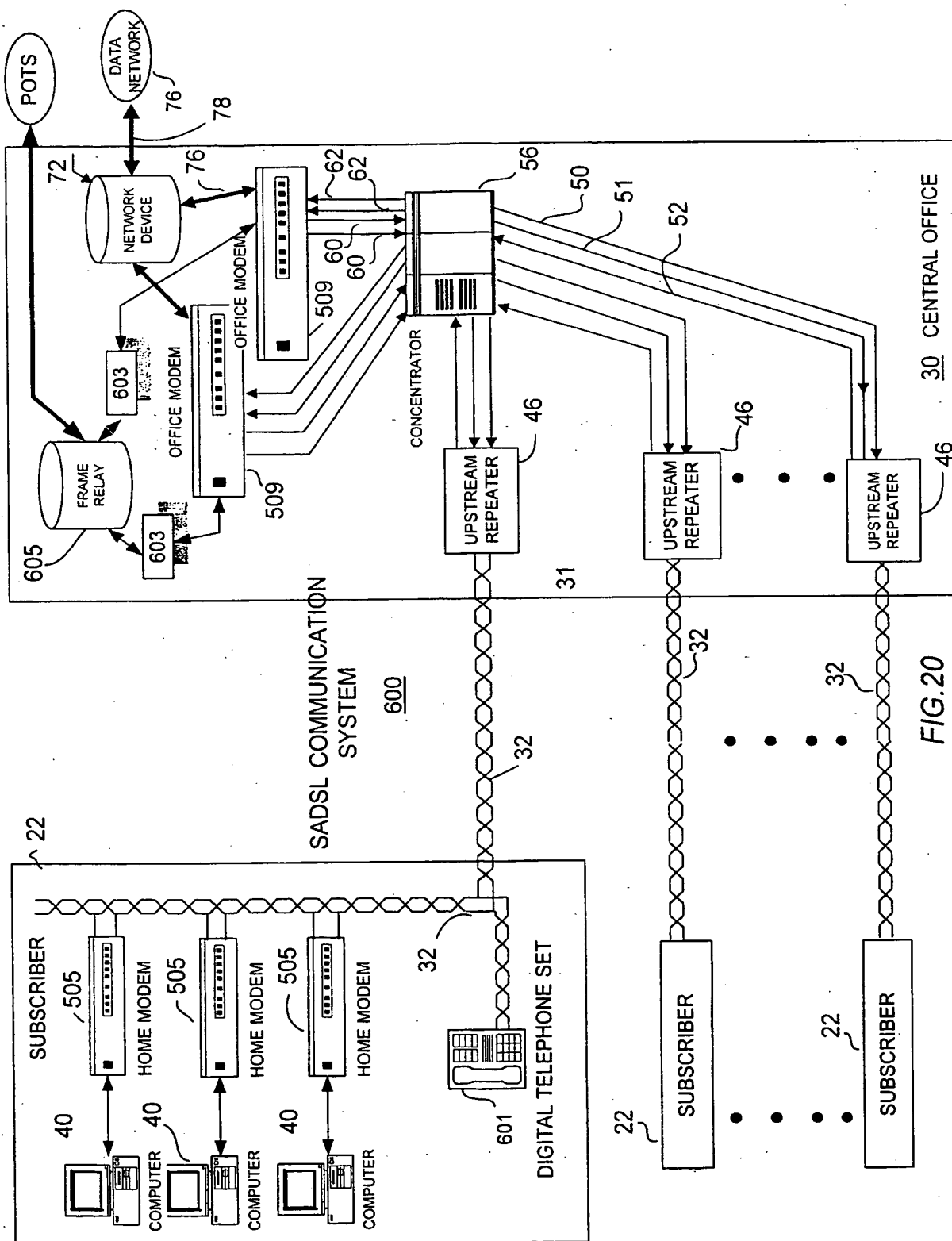


FIG.19



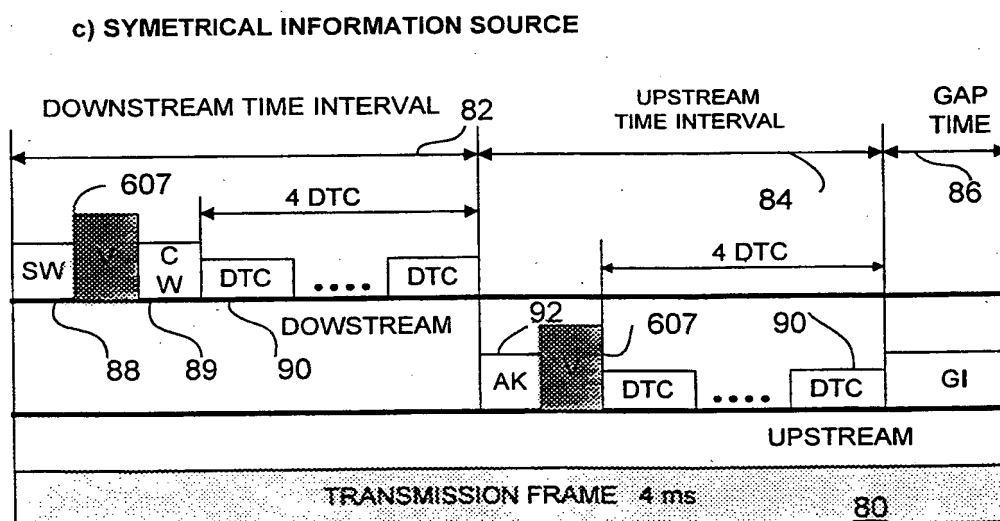
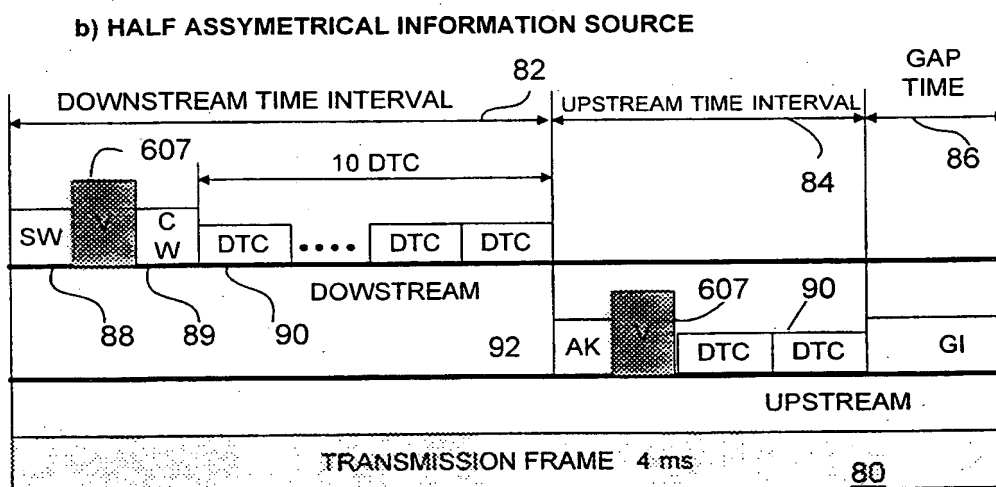
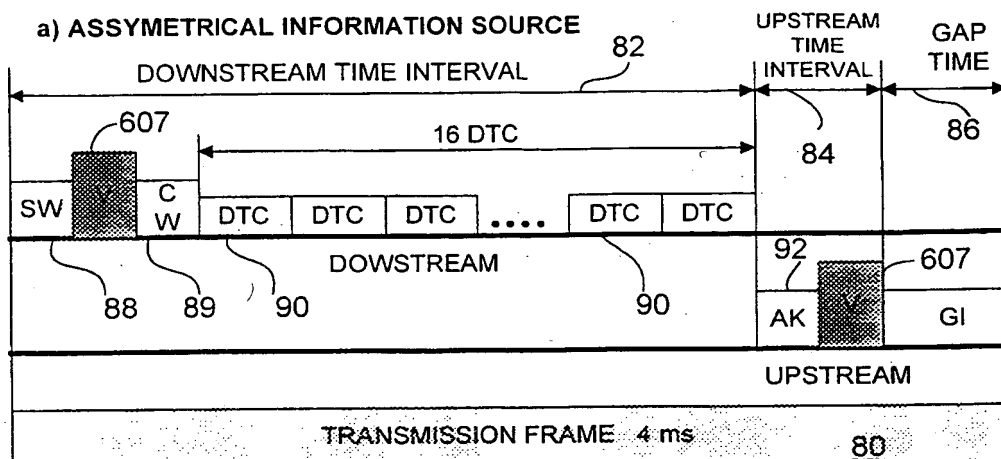
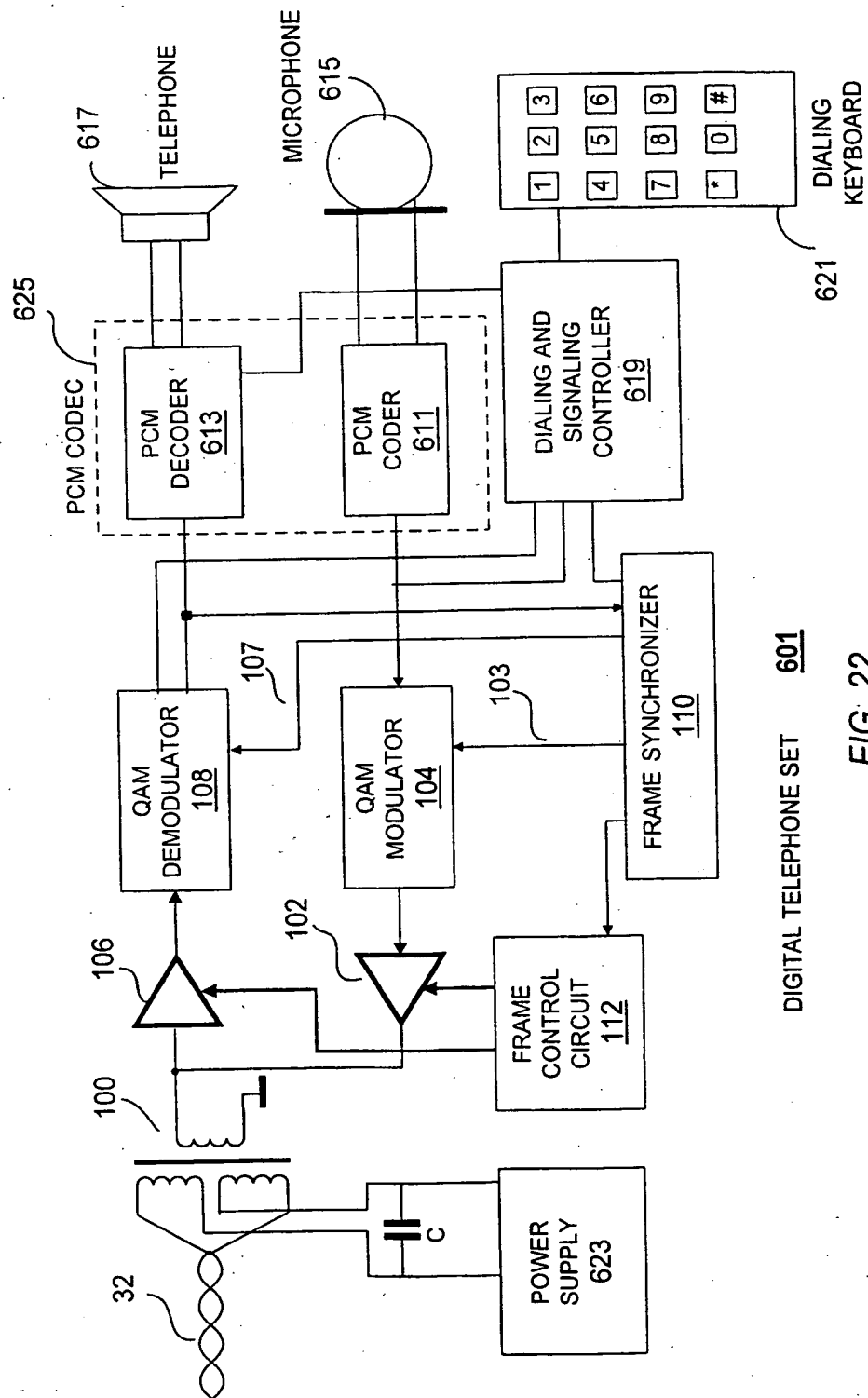


FIG.21





DIGITAL TELEPHONE SET 601

FIG. 22

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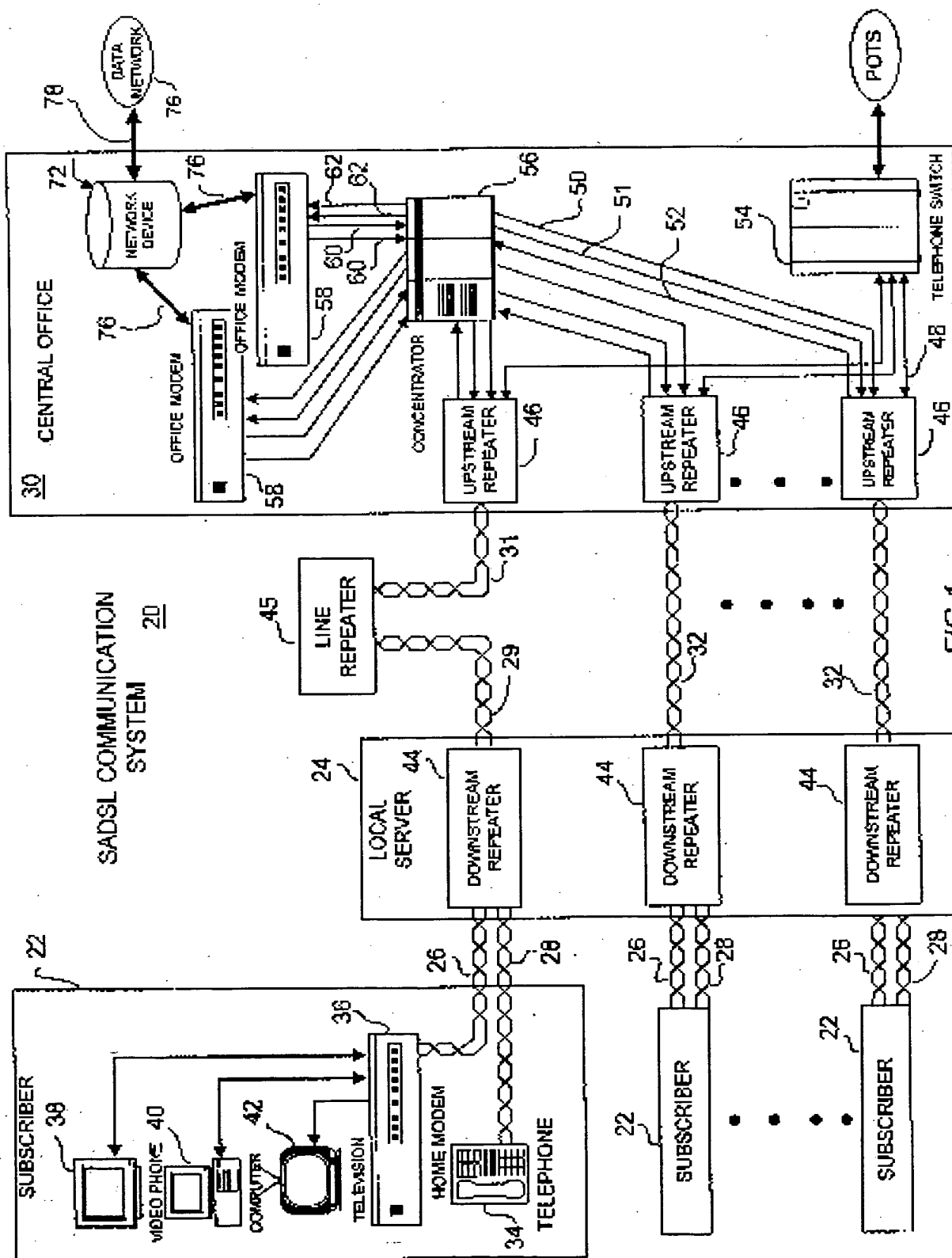


FIG. 1

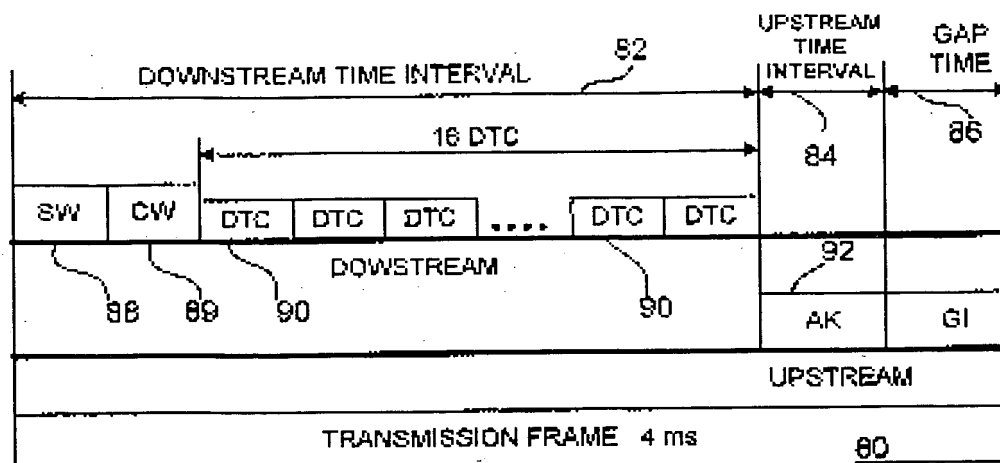


FIG. 2

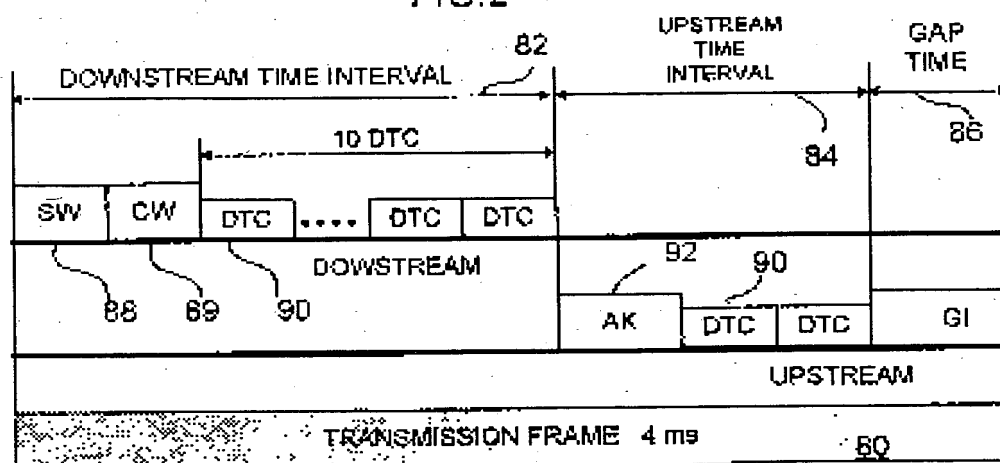


FIG. 3

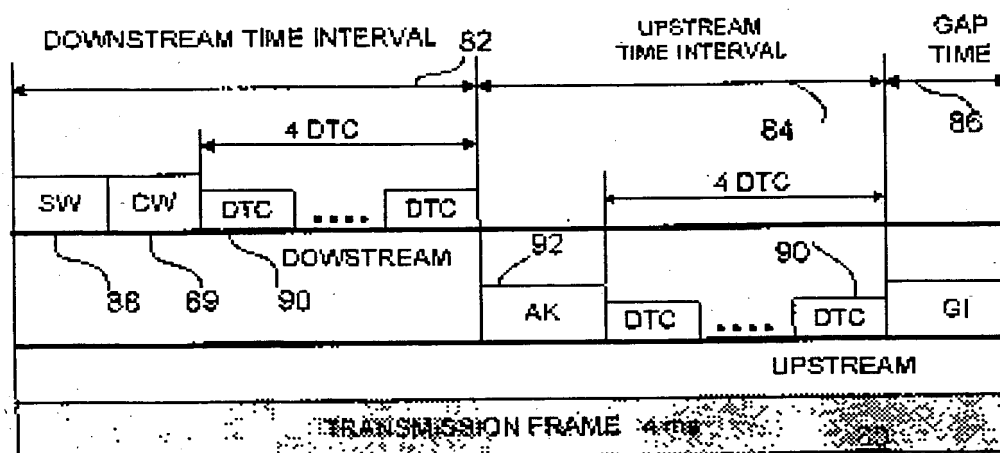


FIG. 4

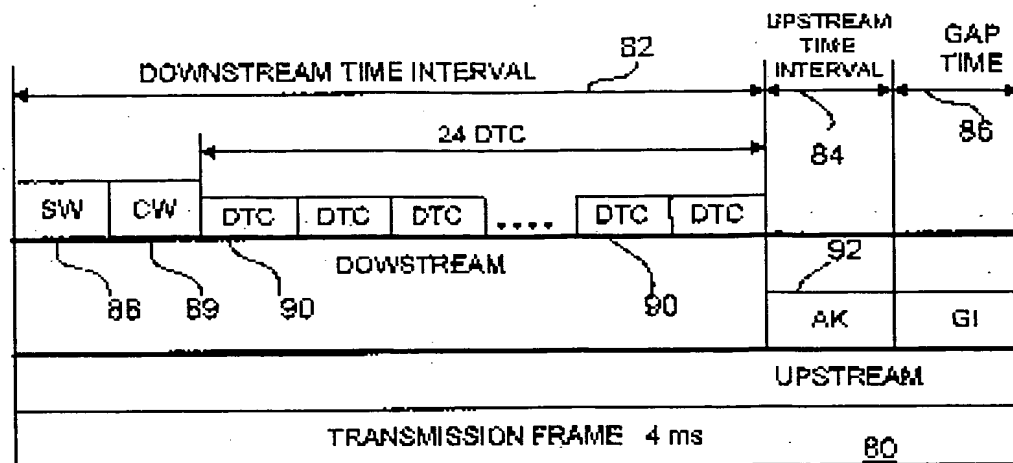


FIG. 6

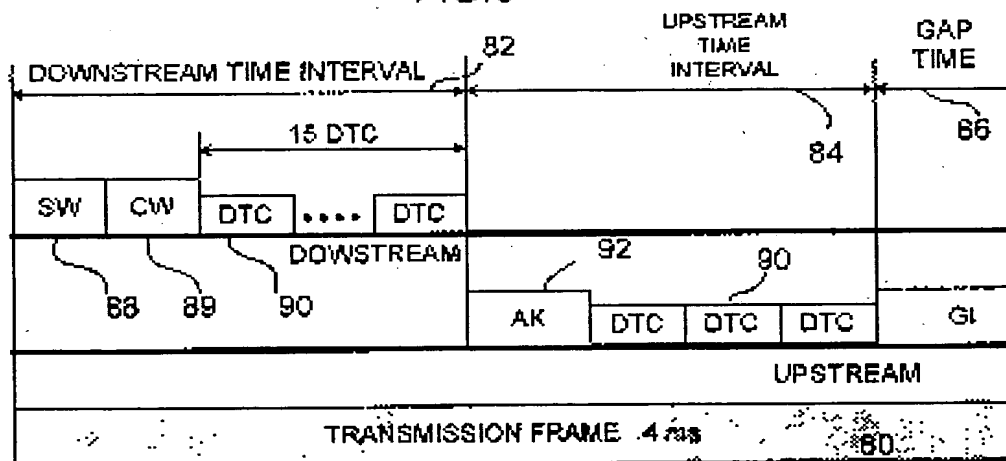


FIG. 7

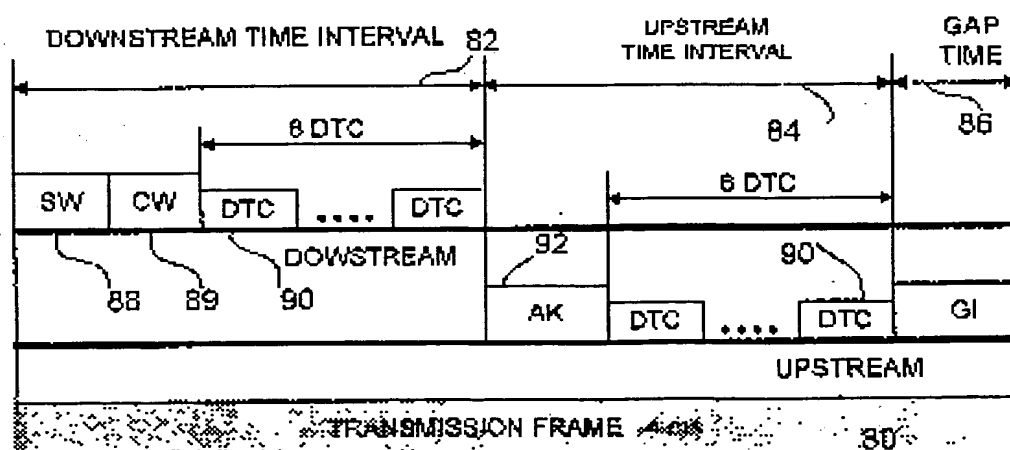


FIG. 8

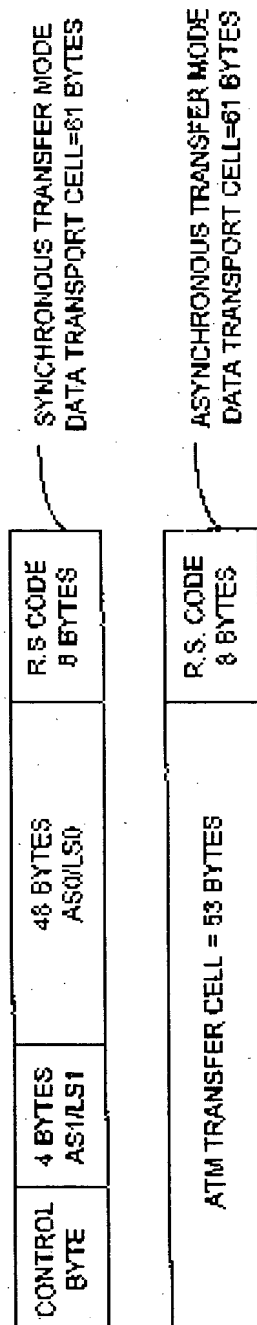


FIG. 5

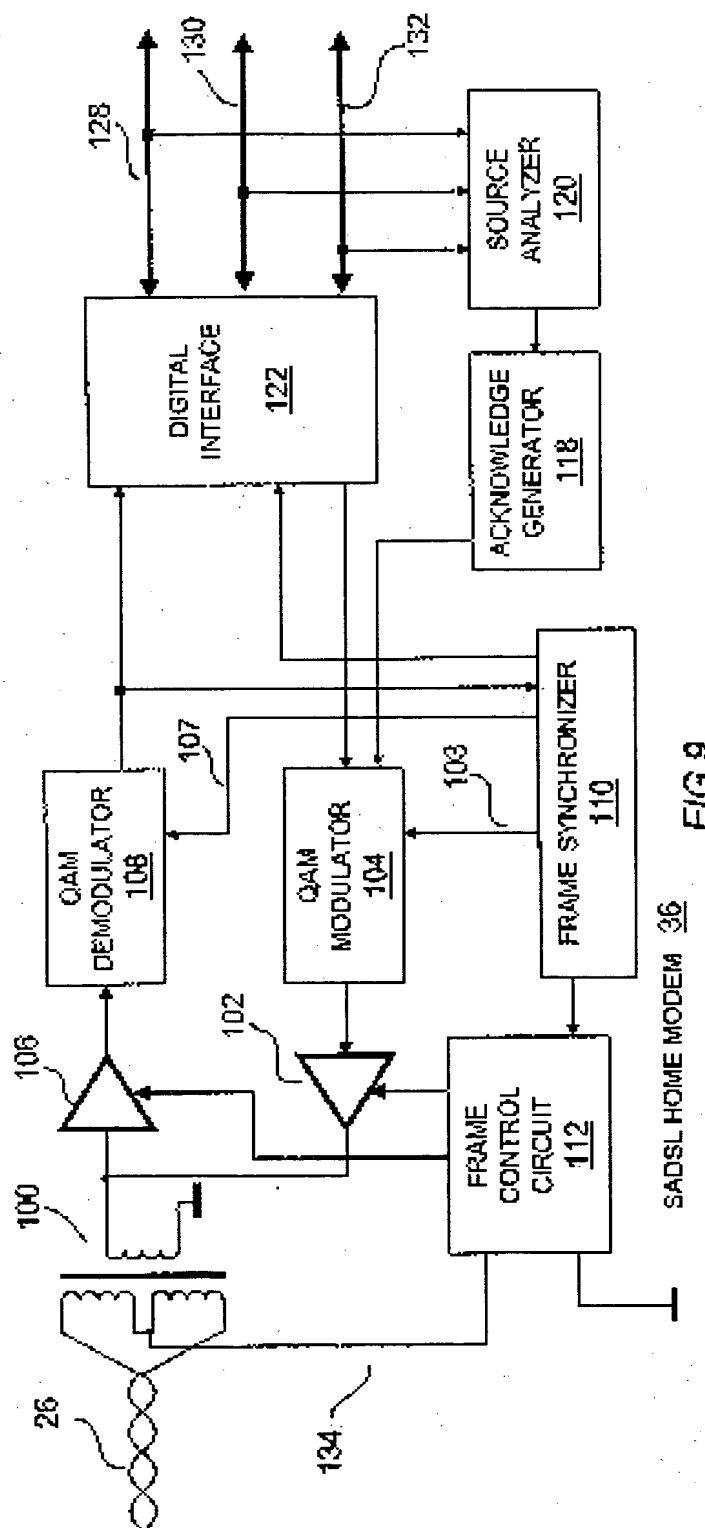


FIG. 9

SADSL HOME MODEM 36

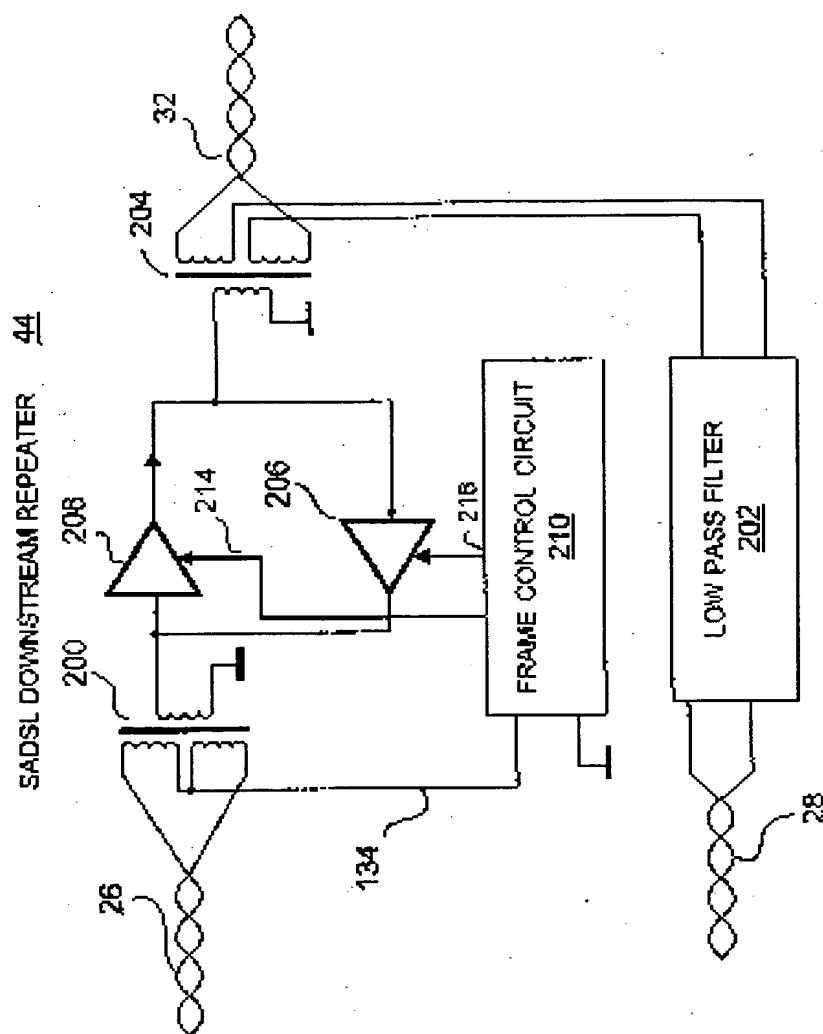
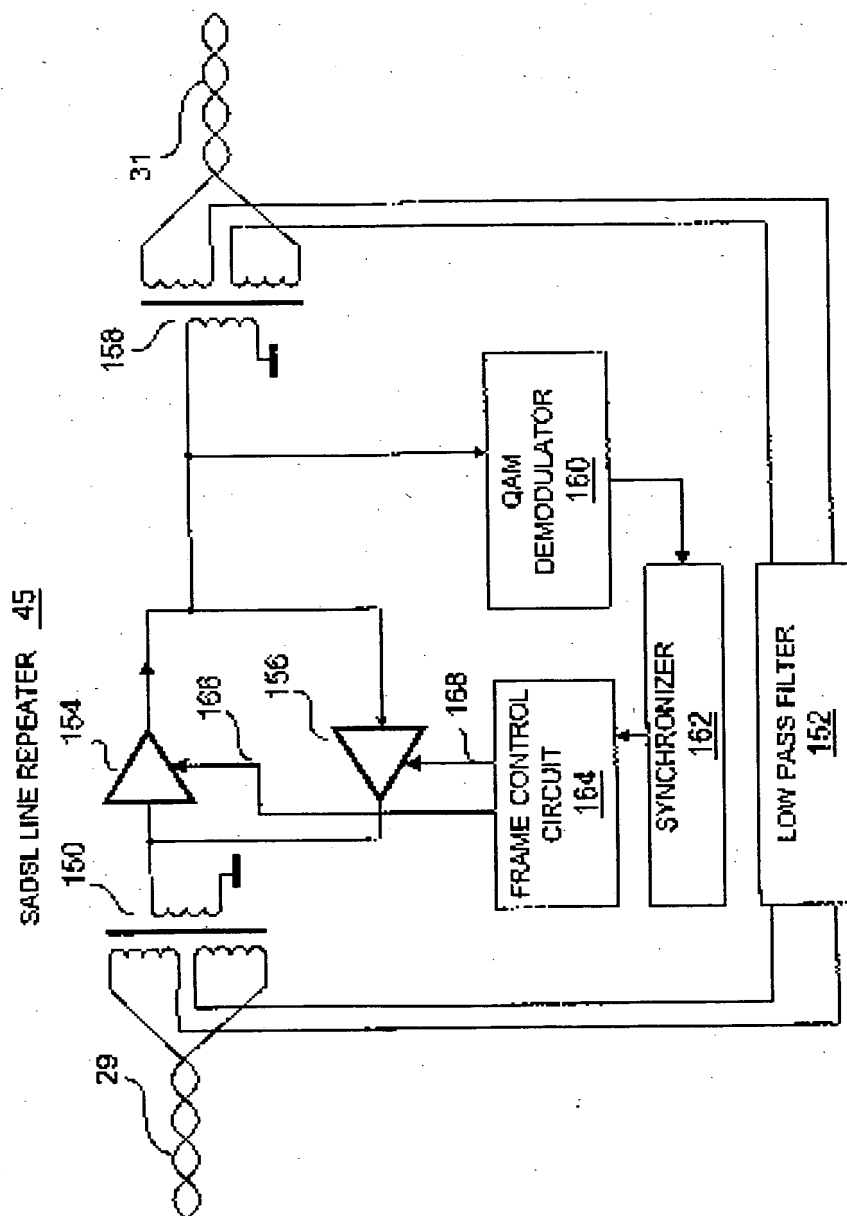
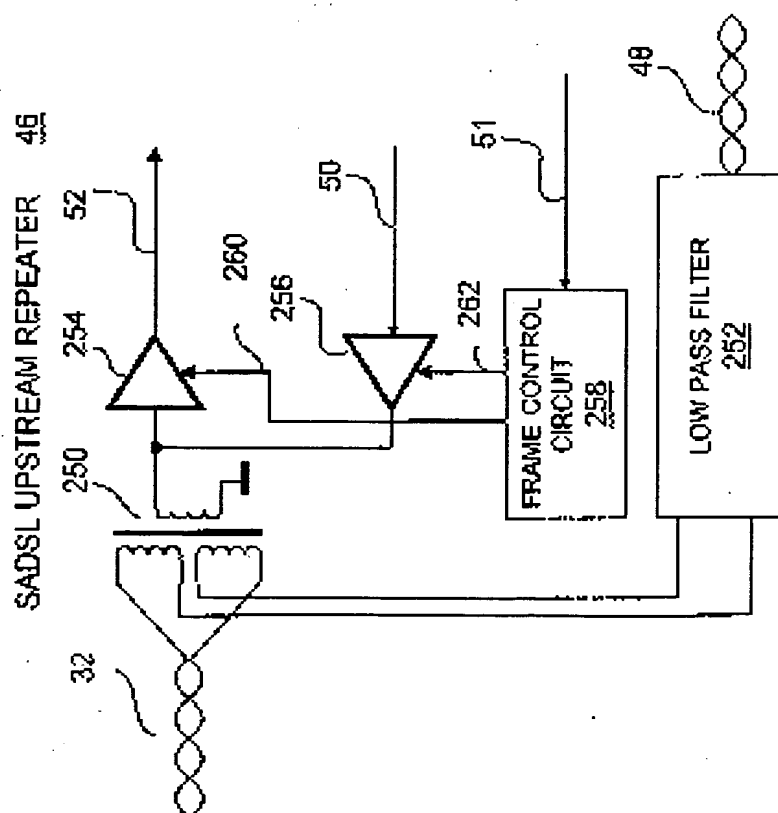


FIG.10



**FIG. 11**





**FIG. 12**

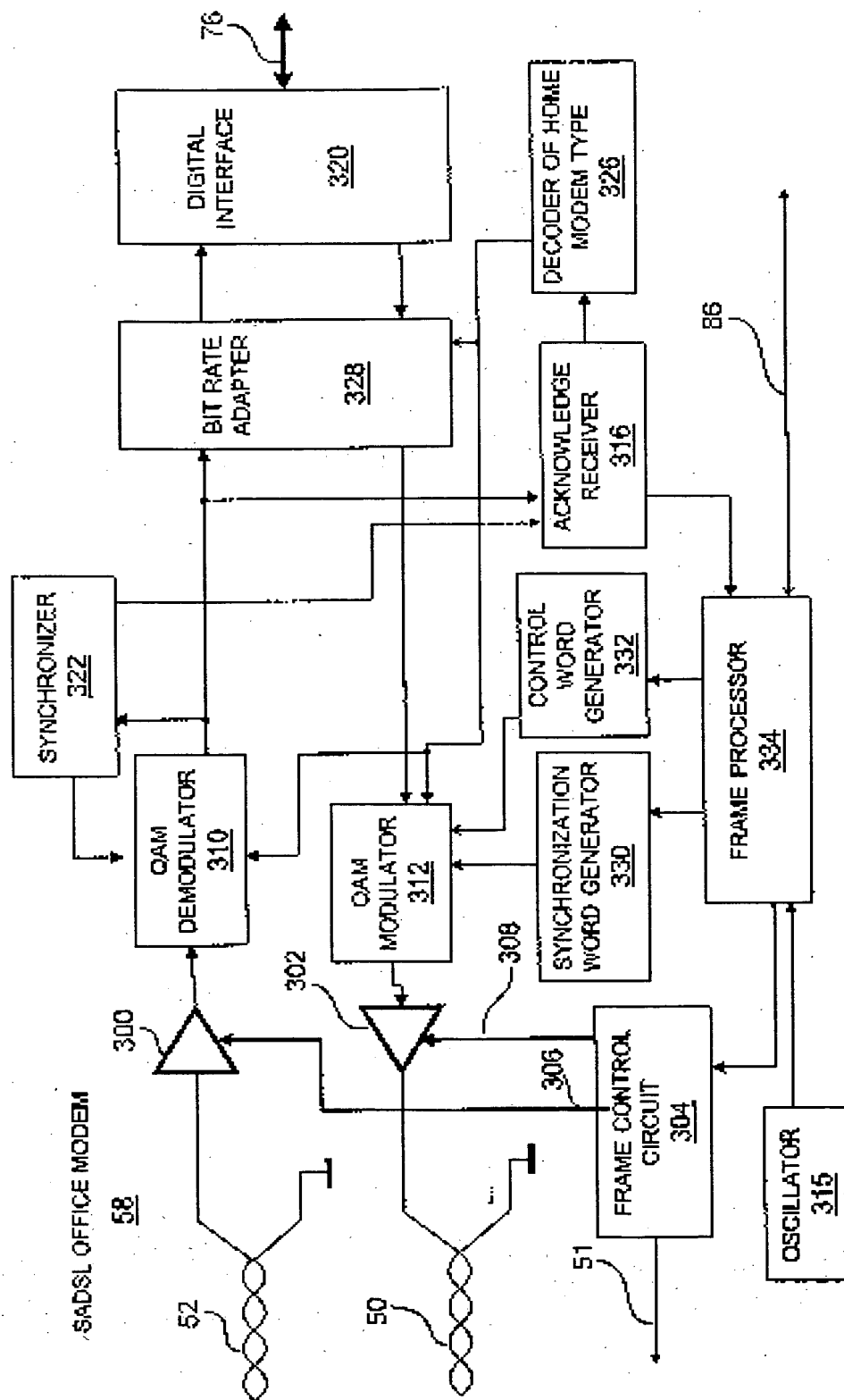


FIG. 13

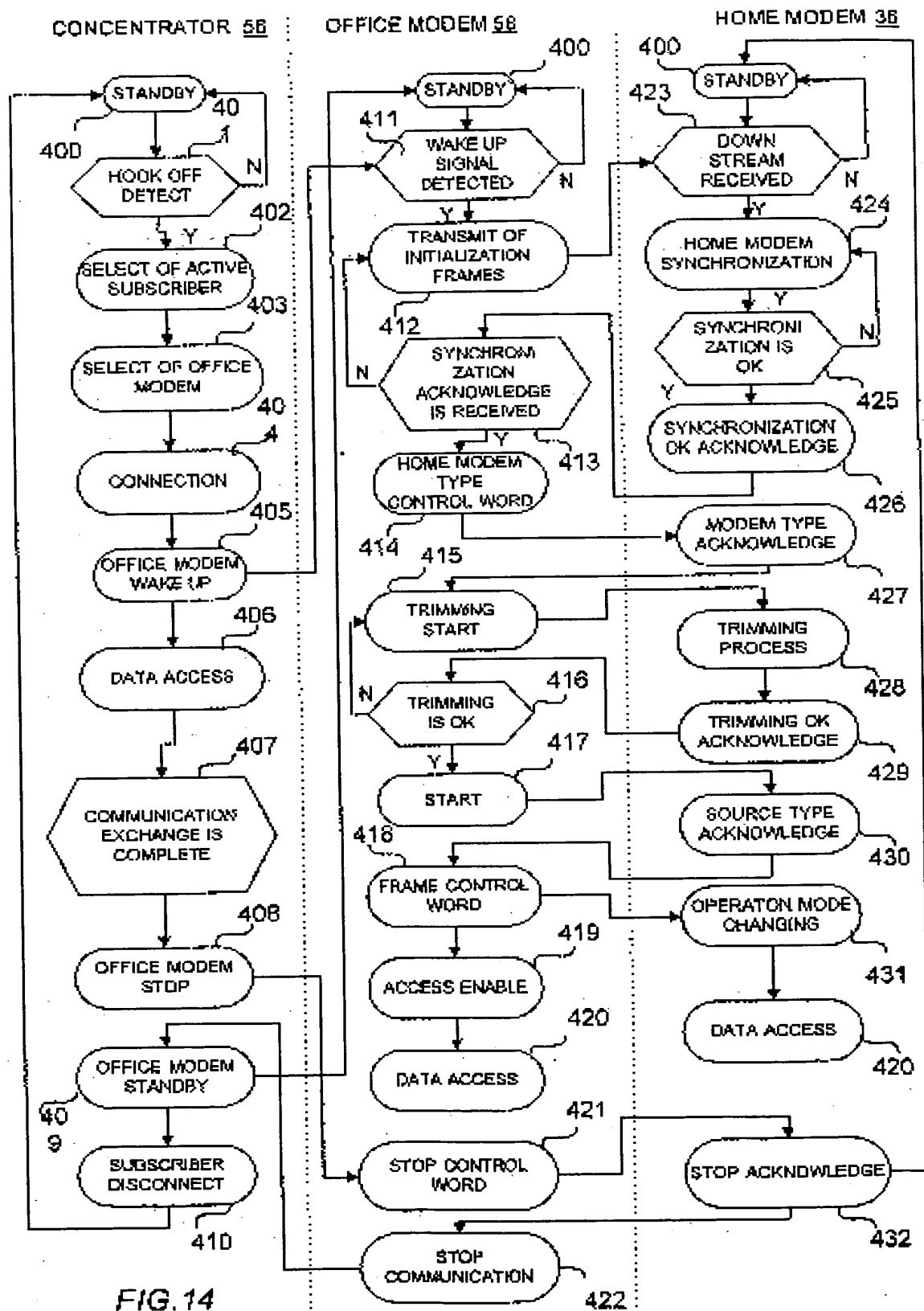
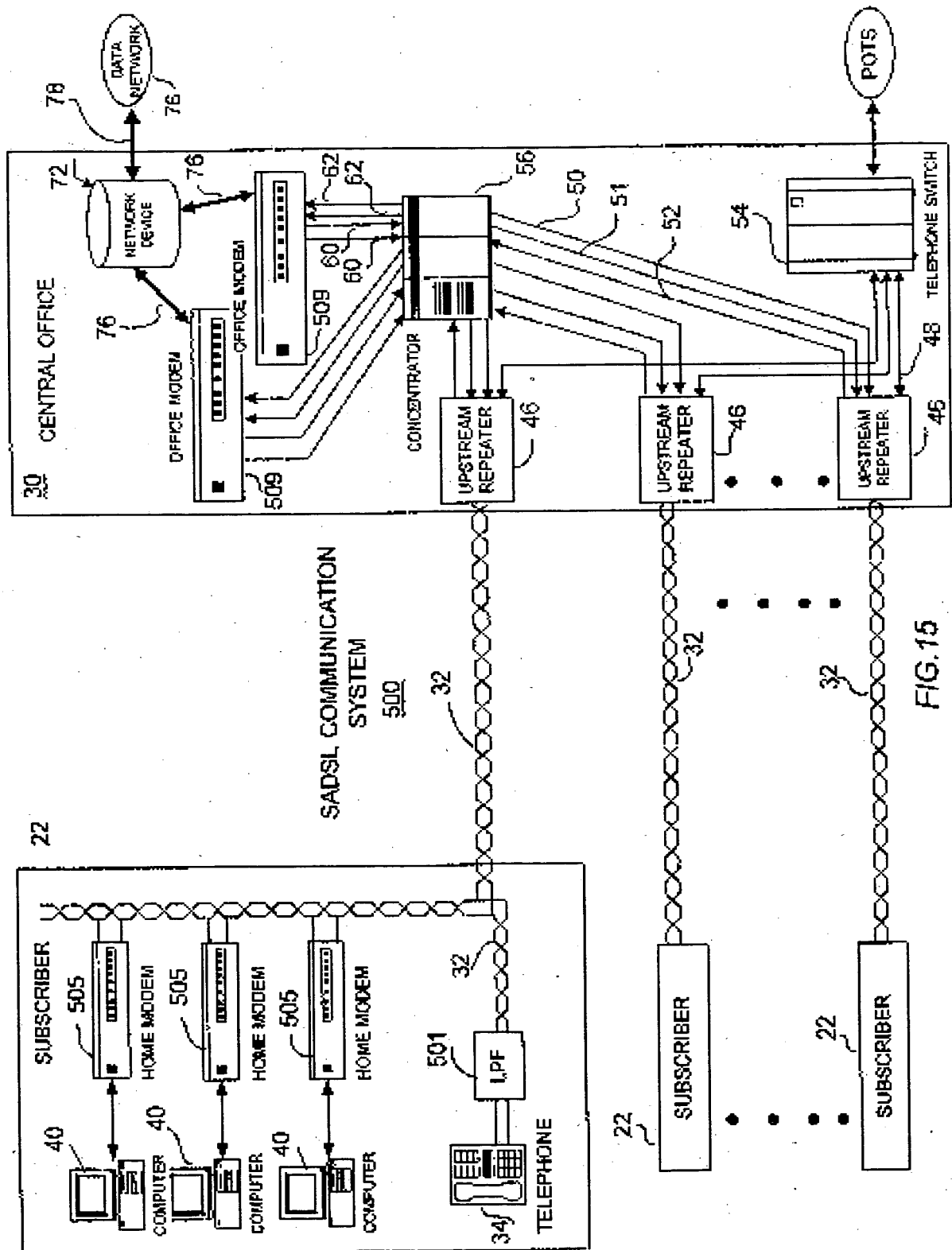


FIG. 14



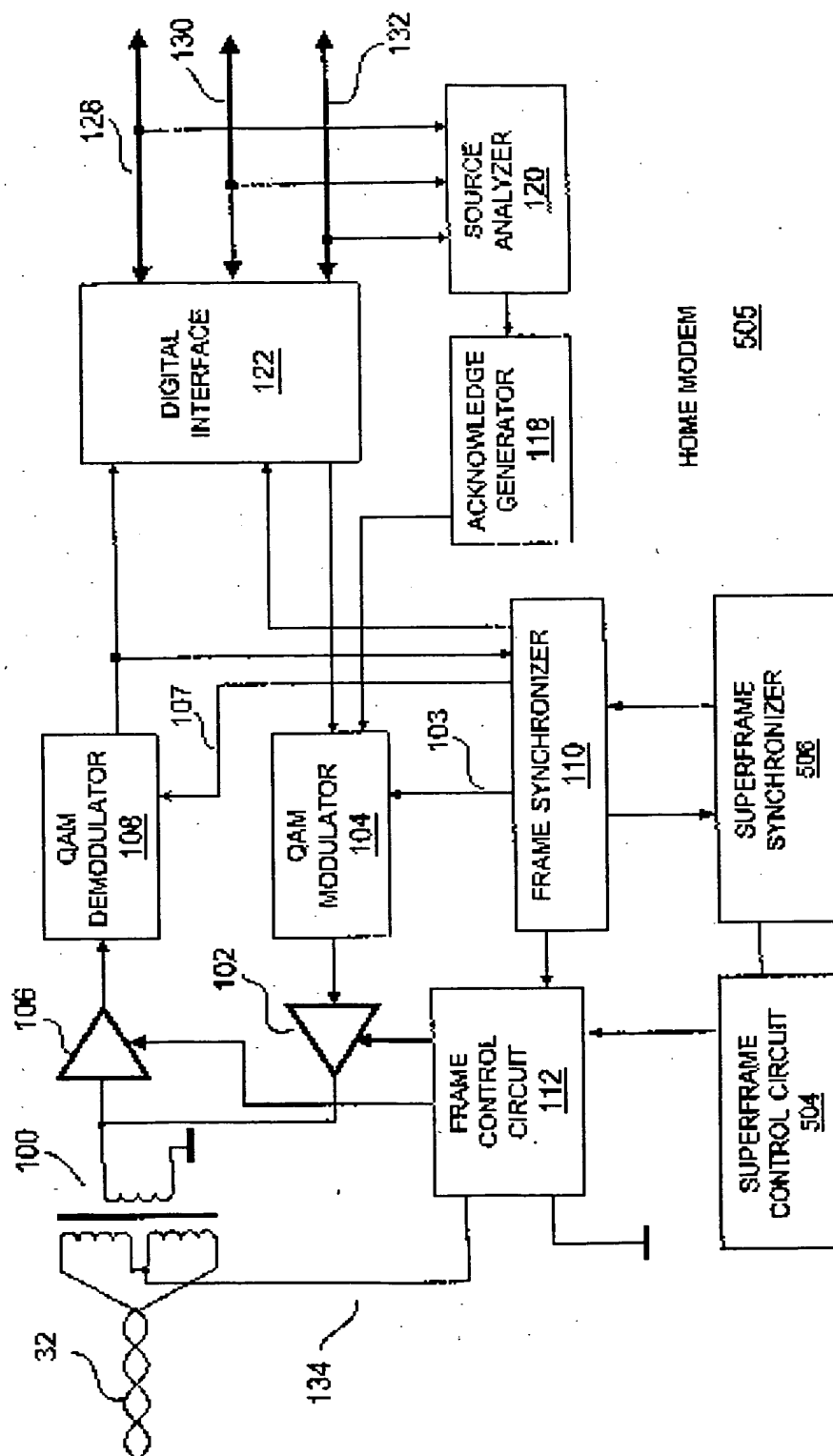
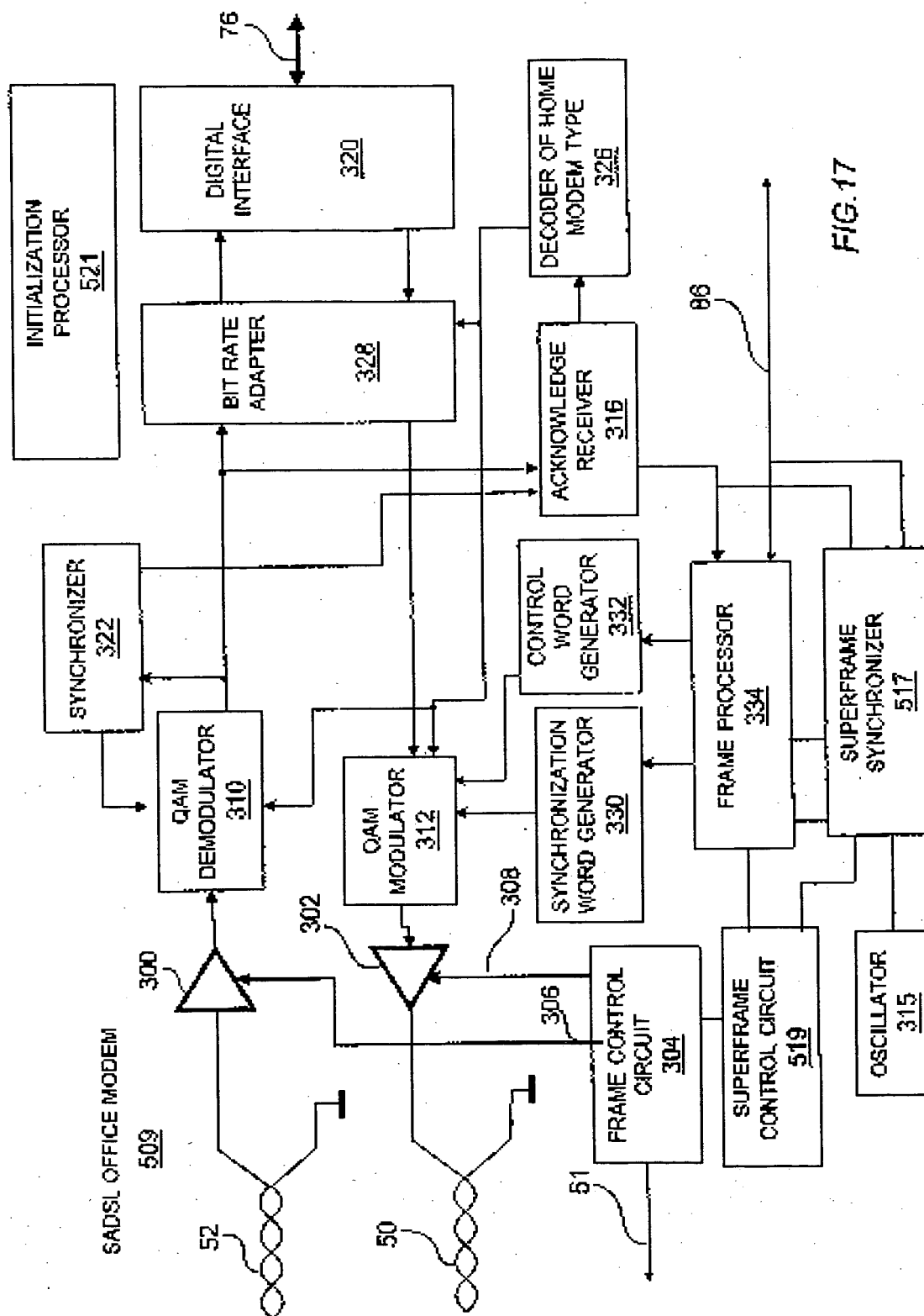


FIG. 16



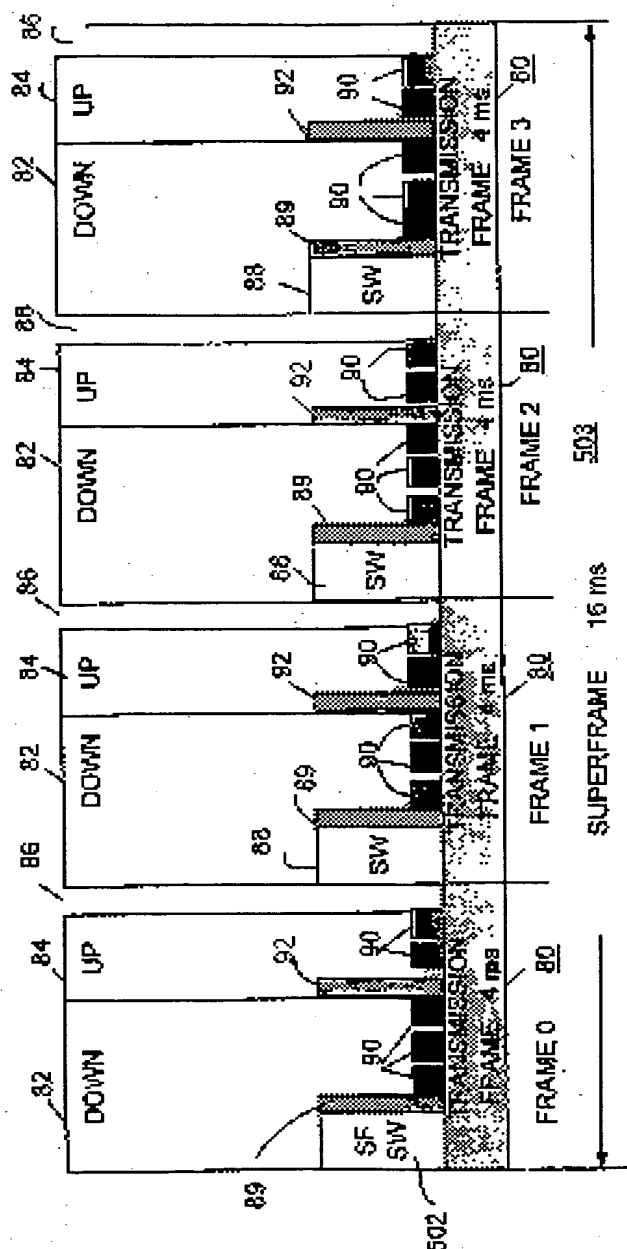


FIG. 18

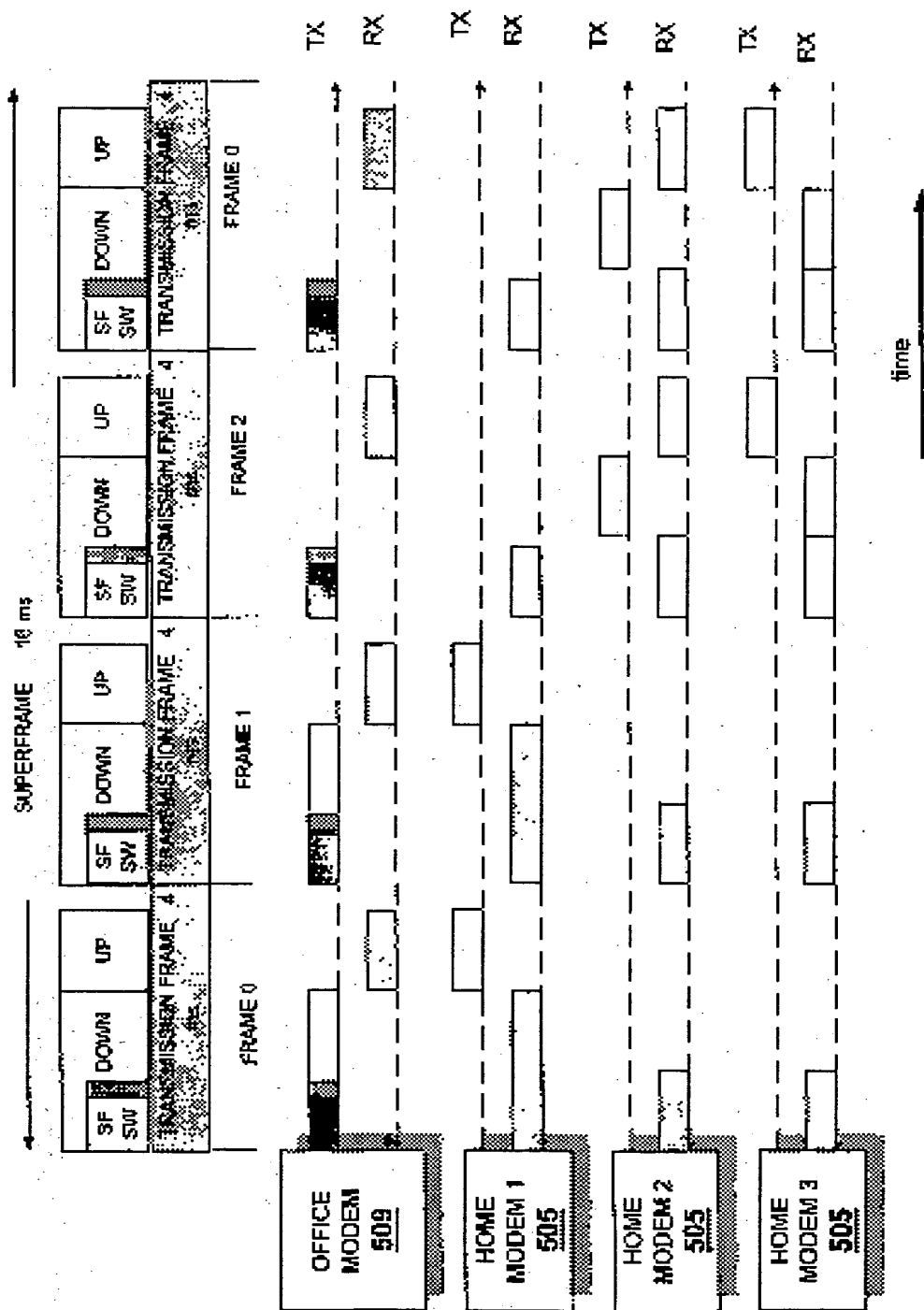


FIG.19



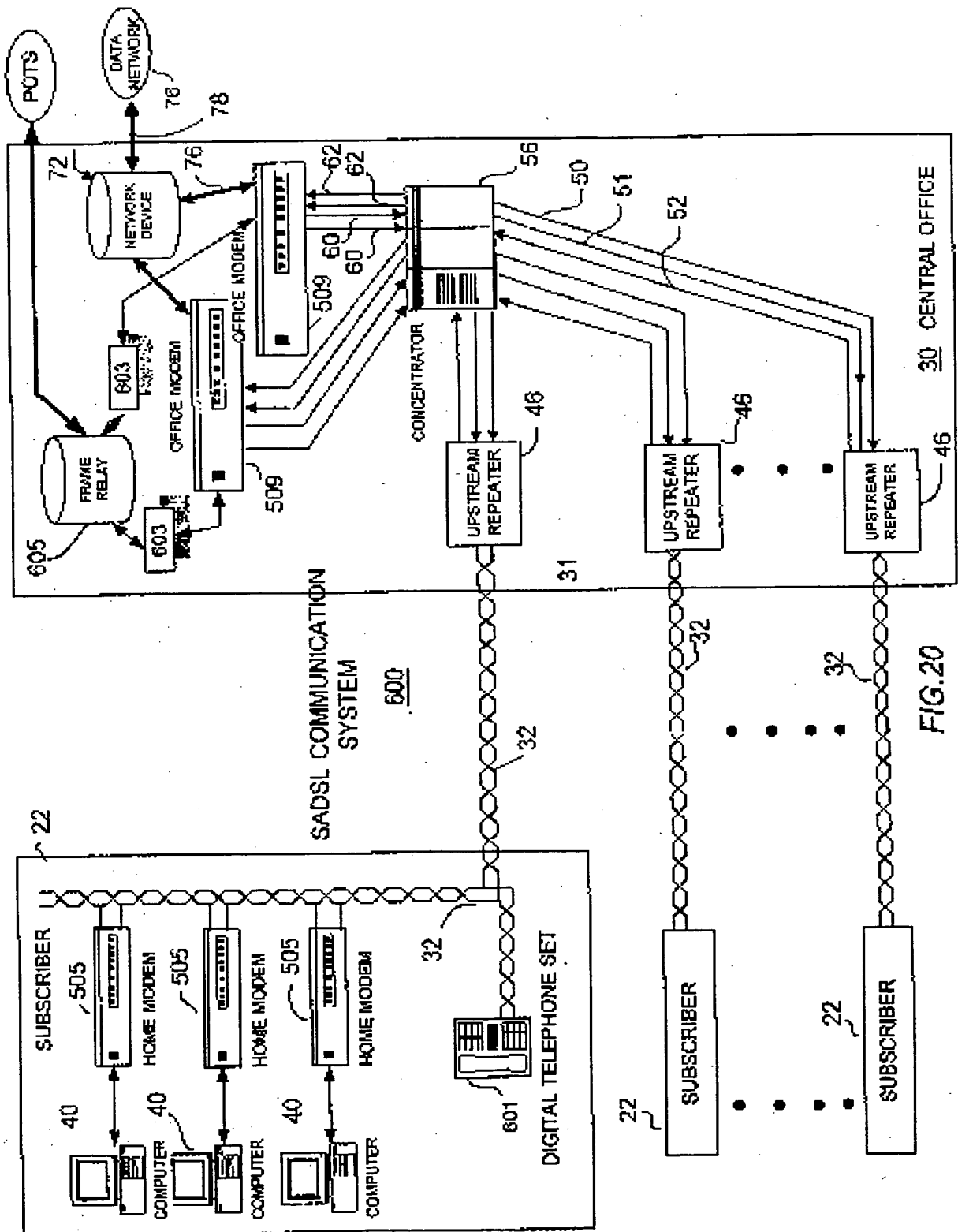


FIG. 20

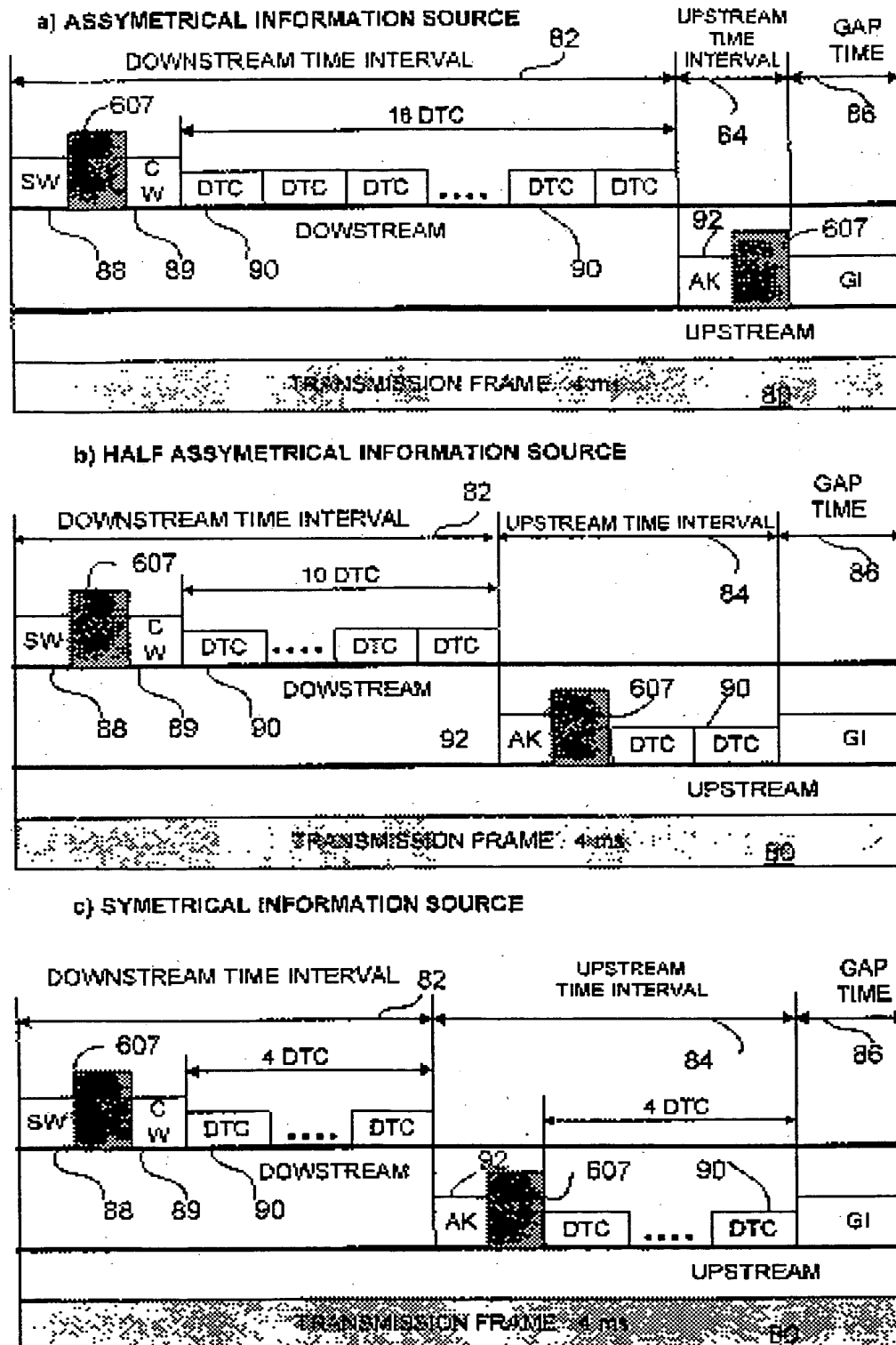


FIG.21

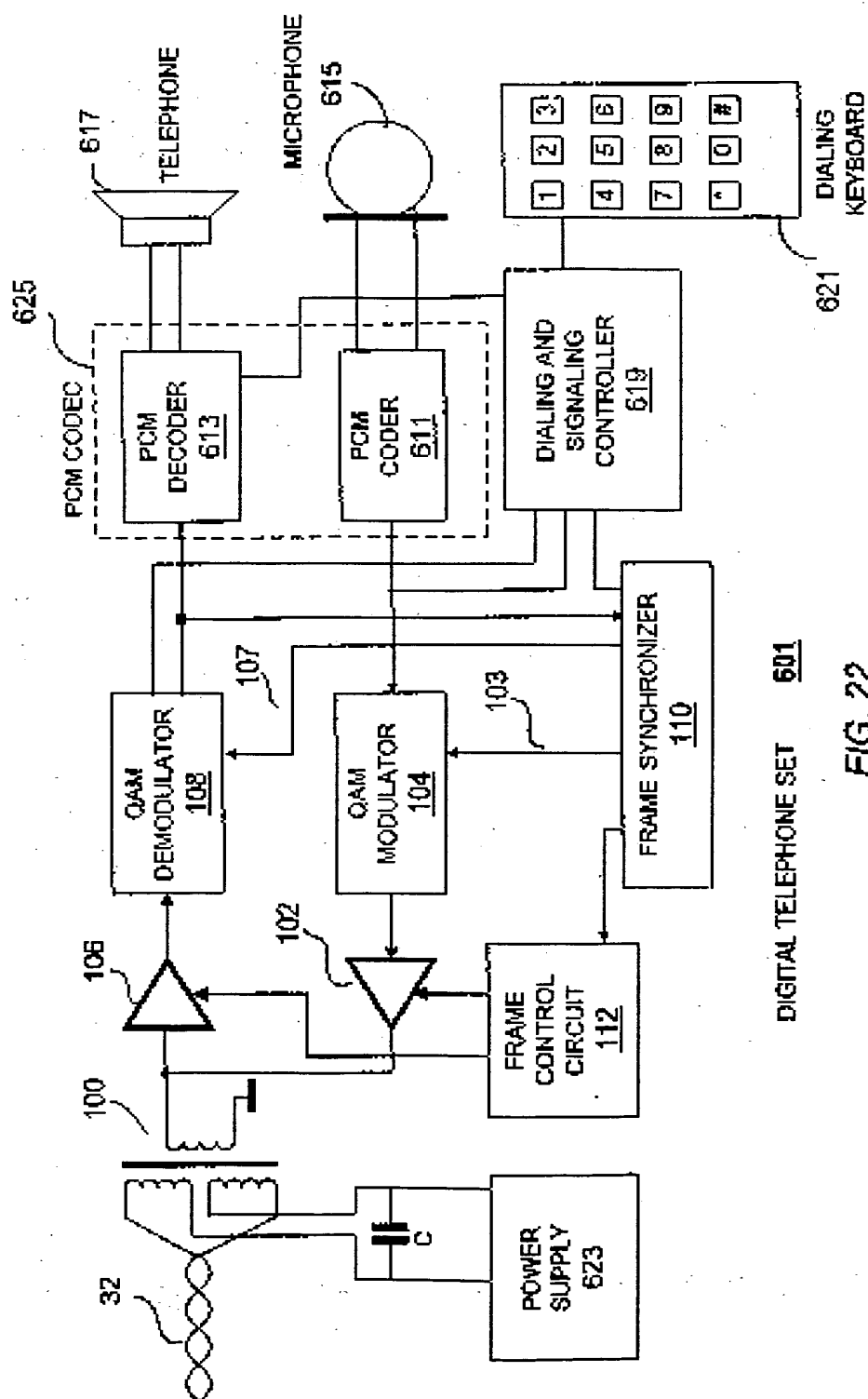


FIG. 22

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Apartment 6, Hadaz Street 9, 58210 Holon (IL).

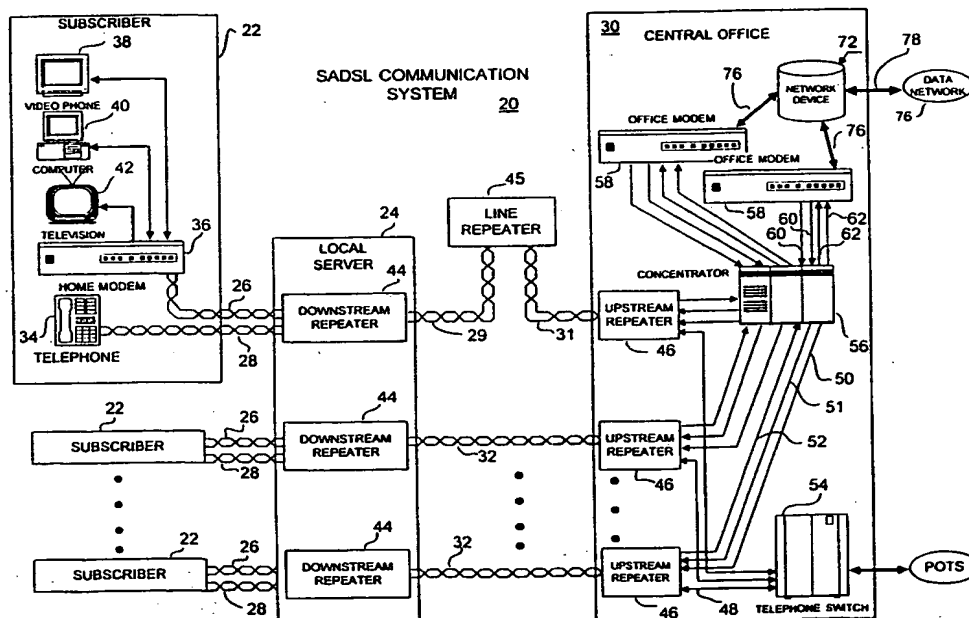
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(54) Title: SOURCE ADAPTIVE DIGITAL SUBSCRIBER LINE AND METHOD

**(57) Abstract**

A communication system includes plurality of subscribers (22) having a telephone set (34) and different types of home modems (36) coupled using twisted pairs to a local server (24) that includes plurality of down stream repeaters (44), a central office (30) coupled to a local server using twisted pair subscriber lines (29, 31). The central office includes a telephone switch (54) that provides telephone service to the subscribers and a concentrator (56) that connects a plurality of upstream repeaters (46) with a number of office modems (58) that provide data service to the subscriber. A communication system uses CAP or DMT line signals with time division. The line signal transmits with different time framing. Every subscriber line can work in one of three operation modes: Asymmetrical mode, Half-Asymmetrical mode, Symmetrical mode. An office modem changes the operation mode of subscribers line and downstream/upstream bit rate depending on the type of an information source and the type of the subscriber home modem that is connected to the office modem in the current transmit cycle.

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## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/IL99/00349**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(6) : HO4L 12/50

US CL : 370/352, 353, 354, 356; 375/222

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 370/352, 353, 354, 356; 375/222HO4L 12/50

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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A	US 5,991,311 A (LONG ET AL) 23 NOVEMBER 1999	1-15
A	US 5,978,381 A (PERLMAN ET AL) 02 NOVEMBER 1999	1-15

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